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European Catchments: catchment changes and their impact on the coast

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R-04/01

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Executive summary

The coastal zone is under heavy pressure from land-based activities located in the catchment of rivers. Traditionally, both scientific research and the governance framework have treated catchments and coasts as separate entities. However, it is increasingly recognised that they should in fact be treated as an integrated whole, encompassing both environmental as well as socioeconomic and political systems.

The EuroCat project was established with an integrated perspective and analytical framework in mind. Across seven regional case studies, local teams of natural and social scientists used a common interdisciplinary strategy to:

- Identify the impacts on the coast;
- Interface biophysical catchment and coastal models with socio-economic models;
- Develop regional environmental change scenarios (2001-2020);
- Link scenarios with the modelling toolbox to evaluate plausible futures;
- Evaluate the research outcomes with regional boards consisting of stakeholders and policy makers.

The seven systems cover all coastal types (with the exception of fjords) in Europe and different socio-economic settings. The approach is novel and not all teams had direct experience of working across geographical boundaries and disciplines, hence the project had a strong capacity building component.

Eutrophication and in one case pollution (metals) were identified as major issues for the coastal zone. Existing locally available modelling tools and data sets were used in the project. Even the most stringent environmental protection scenarios were found to lead to lasting eutrophication. Associated problems in, for example, tourism or mussel farming, remain highly probable. Strategies to combat eutrophication, such as managed realignment and/or wetland creation schemes, together with improved water treatment programmes, or agricultural zoning and regime modifications were, however, much more effective, in the UK and The Netherlands studies.

The regional analyses differ in their complexity and comprehensiveness depending on the type of catchment studied and the availability and strengths of 'local' research teams. However, the main reason for the diversity present in the results and outcomes is a 'planned' one: EuroCat set out deliberately to investigate different catchment-coastal situations both from biogeochemical and socio-economic and cultural perspectives. The overall project also aimed to test different evaluation methods e.g. cost-effectiveness, economic cost-benefit analysis and multi-criteria analysis. Across the spectrum of catchments all these objectives have been met, while allowing for more individualistic analysis within specific catchments in EU and accession economic and societal conditions. The project thus includes a pan-European assessment of catchment-coast interaction incorporating the results from the regional studies.

1. Introduction

The coastal zone is a dynamic area of natural change and of increasing human use. Coastal land is limited and under pressure from human development and, with 75 % of the human population expected to be living in the coastal zone by 2025, it is evident that an extreme competition for space with the natural ecosystem is occurring. Driving forces include population pressure, transport development, industry and tourism. This has led to urbanisation (and mega-cities), increases in transport networks (canalisation and harbours) and tourist sites, together with extensive sea defence and coastal protection works, at the expense of the footprint available for the ecosystem. Impacts include changes in substance flow (e.g., sediments, water, nutrients and contaminants), loss of habitats, bio-diversity and related cultural assets. Apart from regional drivers and pressures in Europe itself, the changing coastal footprint is the result of global drivers and pressures including climate change.

The policy and management challenge is to ensure the sustainable utilisation of coastal resources under intense and changing environmental pressure. The management process that is required must be a continuous, adaptive, day-to-day process, carried out by a mix of public and private entities. The necessary scientific knowledge and know how base is currently deficient. A major effort is required both to integrate within disciplines, as well as across the natural-social science divide.

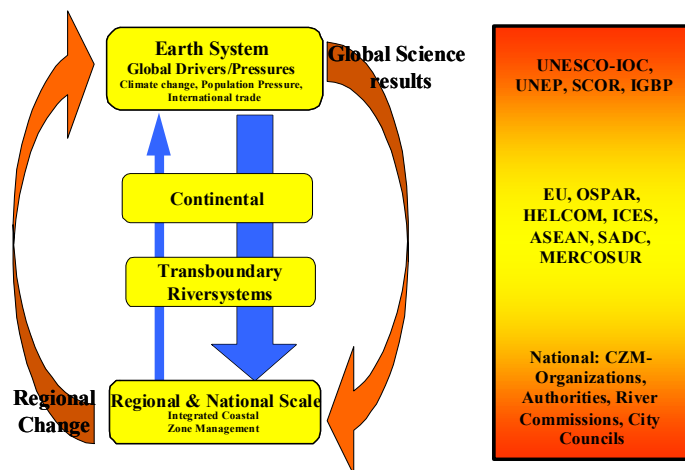


Figure 1 Scaling of catchment-coast studies from regional to global and their respective users.

Scientific advances are necessary to support a sustainable utilisation strategy to reduce uncertainties over the precise linkages between catchment-coastal processes and systems, the likely influence of climatic change and the impacts on and feedback effects from socio-economic systems and activity levels. A survey (LOICZBasins) carried out as part of the IGBP-LOICZ program, showed that our current limited understanding of regional and global changes and the different scales through which they impact local coastal systems hampers effective responses to this challenge.

At the local level the challenges to be addressed include:

- Identify, model and analyse those *global changes* which affect the local system: such as natural variability, climate change and associated changes in the hydrological cycle, and those due to changes in the global economy/trade and policy;
- Identify, model and analyse the *regional (trans-boundary and supra-national) changes* which are primarily the result of regional and national drivers and pressures in the coastal zone;
- Model and assess the *regional changes* at the river catchment level (damming, land use change) which affect the downstream coastal zone;
- Map the existing *stakeholders interests and differences* in the perception of coastal values at regional scales including differences which need adaptation of management options to local social conditions, beliefs and attitudes; and
- Formulate and implement efficient and effective policy responses, which minimise the scaling mismatch problems and promote sustainable management

Sustainable Management and its supporting research have to take these interrelated changes into account and therefore require an holistic approach. In this holistic approach the coastal region is part of the catchment-coast continuum and part of a regional socio-economic framework that is embedded in a global setting. The EuroCat project is one of the few examples in which scientists worked together on an integrated catchment-coast scale.

2. The EuroCat project

Approach

The pace and extent of change in the continuum catchment-coast is controlled by an increasingly complex set of biogeochemical and socio-economic interrelationships and feedbacks, such that some analysts refer to the concept of coevolution in their analysis. In order to scope the many issues, problems and arguments surrounding the scientific analysis, valuation and management, a simplified organisational and auditing framework can prove useful. In this project such a framework, the Drivers-Pressure-State-Impact-Response (DP-S-I-R) approach (Figure 2), has been adopted to underpin the regional studies and allow integration at the European level. The DP-S-I-R approach although simple is still flexible enough to be conceptually valid across a range of spatial scales.

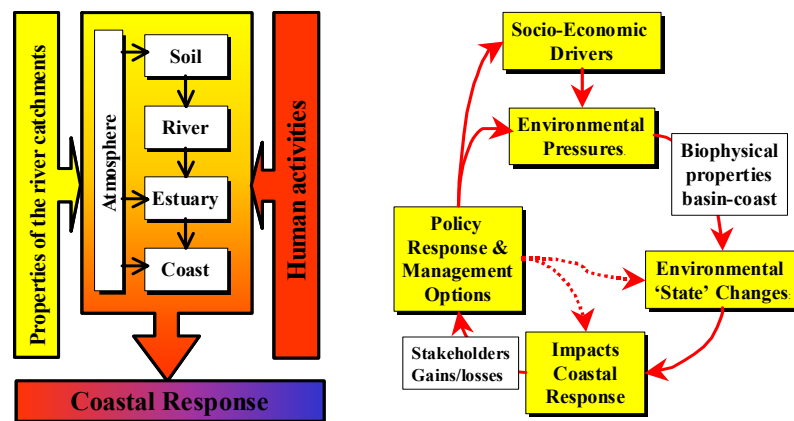


Figure 2 The catchment-coast as one system and the DP-S-I-R Framework.

It also highlights the dynamic characteristics of ecosystem and socio-economic system changes, involving multiple feedbacks within a possible coevolutionary process. Environmental pressure builds up via socio-economic driving forces – demographic, economic, institutional and technological – which cause changes in environmental systems ‘states’. These changes include increased nutrient, sediment and water fluxes across drainage basins and into the marine environment; land cover and use changes, fragmentation and degradation of habitats; pollution of soil, water and atmosphere; and climate attention. The severity of some of the resulting damages is increased because of the variability (natural and induced) of coastal processes. Where the functioning capabilities of ecosystems are affected, human welfare consequences are felt. Social welfare losses occur because of productivity, health, amenity and other value changes. These impacts impose welfare losses and gains across a spectrum of different stakeholders, depending on the spatial, socio-economic, political and cultural setting. Policy response mechanisms will then be triggered within this continuous feedback process.

In this project we will evaluate those changes at the catchment level, which impact the coastal zone: e.g. using coastal response for catchment “performance”. In this case drivers refer to those forces and interactions at the catchment level, which are likely to

change the coastal system. These activities (and also implementation of regulations) cause a response in the coastal region often after considerable time delays. The flow of substances is modified both temporally and spatially by the biogeochemical properties of the basins and the estuaries. Hence, contrasting regional studies are needed to quantify the spatial and temporal response of catchment fluxes to changing pressures and drivers.

The case studies

In EuroCat initially 5 case studies were performed along the catchment-coast continuum and in 2002, two additional contexts were added. Hence, the final EuroCat project incorporates 7 biophysically contrasting catchment-coast systems in its analysis, which cover all coastal types (with the exception of fjords) in Europe (Meybeck et al., 2004a). The rivers Vistula, Rhine, Elbe, Idrijca and Axios are transboundary rivers.

These systems are located in Northern Europe, the Mediterranean and three NAS countries and as such also address the variability in socio-economic conditions in Europe. However, each selected catchment has unique characteristics. The Rhine represents transboundary issues and illustrates a context of a is well-documented and implemented management plan at the catchment level. The Elbe catchment and associated estuary and coastal sea went through a relatively recent and rapid change because of politico-economic changes in the catchment (central to market economy) with a corresponding change in fluxes to the coast. The Vistula and Provadijska catchments are undergoing similar changes albeit at a slower pace. The Axios is a complex example of agricultural and industrial change on the catchment, accompanied by political and socio-economic transition (central to market) in FYROM, where 95% of the upstream catchment is located. The Po is a prime example of the influence of a catchment dominated by intensive agriculture on coastal sea functions and in particular tourism.

The case studies in EuroCat.

1. Rhine-Elbe catchment and North Sea (RebCAT);
2. Humber catchment and Humber estuary (HumCAT);
3. Vistula catchment and Bay of Gdansk (VisCAT);
4. Po catchment and North Adriatic Sea (PoCat);
5. Axios catchment and Bay of Thessaloniki (AxCAT);

In 2002/2003 two additional case studies were added:

6. Idrijca catchment and North Adriatic Sea (IdriCAT);
7. Provadijska catchment and Black Sea (ProvaCAT);

(a total of 23 participating institutes and approx. 70 scientists.)

Most toxic substances, and in particular heavy metals, show a downward trend in their fluxes from the catchments. In mature post-industrial river catchments like the Rhine, the diffuse sources are similar or exceed the point sources. However, in many estuaries and coastal areas in Western Europe the legacy of past industrialisation and past absence of regulations on emissions is still present in the sediments. The problems this issue poses and their solutions, together with nutrient fluxes, are part of the Humber study. The Idrijca is an example of the impact on the coast of mercury pollution due to a past legacy of hundreds of years of mining for mercury in the catchment.

EuroCat conceptual framework: work packages.

SCOPING ANALYSIS

DP-S-I-R framework, common application across all catchments preliminary identification of priority science/policy issues

INSTITUTIONAL, STAKEHOLDER AND POLICY ANALYSIS

Legislation, regulations, institutions across local, national and regional sea spatial scales

SCENARIO ANALYSIS

construction of basic scenarios in order to differentiate between worldviews

BAU - trend future

POLICY TARGETS (PT) - compliance plus future

DEEP GREEN (DG)-environmentalist objectives over the medium term but constrained by technological feasibility (BAT) and social attitudes and cultural changes

CATCHMENT-COASTAL ZONE MODELLING

Adaptation, set-up, validating of existing models for the catchments, estuary and coastal zone

TRANSLATION OF SCENARIOS: INPUT TO BIOPHYSICAL MODELS: Running of the scenarios, analysis of output.

POLICY ANALYSIS OF THE SCENARIOS

ASSESSMENT IN THE EUROPEAN CONTEXT

Turner (2002)

Research in EuroCat is brought together in an holistic approach to enable the development of management tools adapted to regional conditions in Europe. This requires integrated teams working together to cover a variety of natural and social sciences disciplines in each of the regional case studies. The project delivered scientific tools and concepts for an integrated management of coastal seas and catchments. However, it is an established fact (also stressed in the recent EU report "Lessons from the European commission's demonstration programme on integrated coastal zone management") of DGXI on CZM) that these tools generally are too complicated for a manager or policy maker to use directly. To overcome this problem regional Policy Advisory Boards (PAB) assisted the project in extracting and adapting information from the project so that it is suitable for managers.

The DP-S-I-R framework was the basis for a scoping analysis of the regional catchment-coast cases (EuroCat, 2004). Eutrophication was considered to be important for the Vistula, Elbe, Rhine, Humber, Po, Axios and Provadijska Studies. Heavy metals were of prime concern in the Idrijca case study (mercury) and also identified in the Humber as a major issue. The numerous treaties and policies in the various regional studies which are relevant for the catchment-coast continuum have been compiled (Lukewille (2003), analysed (Ledoux and Turner, 2003a) and put in an European perspective by Hisschemöller and Van Tilburg, 2004).

Existing mathematical models for the catchments and the coast were identified and linked. In this way providing a first linked model exercise for the catchment-coast continuum. The Chapters 4 and 5 highlight catchment and marine modelling. Kannen et al., (2004) summarize the results within EuroCat on marine modelling and the attachment give a complete account of the models used and their link with the catchment models and the scenarios. Catchment modelling is discussed in detail in Behrendt (2004).

Scenarios are an integral part of the project. For each regional project scenarios adapted to local conditions were developed through story lines. In all studies a Business as Usual

(BAU), Policy targets (PT) and Deep Green (DG) were considered (Figure 3). The scenarios were used to generate an array of inputs for the catchment- coastal zone modelling and the results were analysed in terms of their impacts on nutrients reductions. Results were analysed either as concentration of nitrogen and phosphorus, by using the TRIX indicator or by a newly developed indicator based on ecosystem integrity (Kannen et al., 2004). These results were subject to an economic and policy analysis (Turner 2004). Three reports put the pan-EuroCat project in an European context (Meybeck et al., 2004a,b and c).

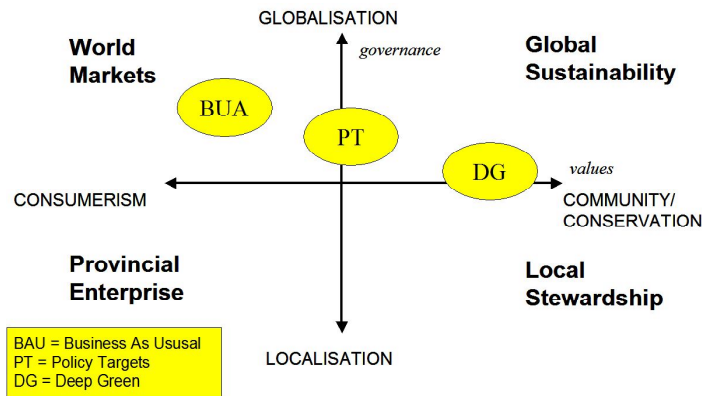


Figure 3 *The Business as Usual (BAU), the Policy Targets (PT) and the Deep Green (DG) EuroCat standard scenarios in the concept of "Environmental Futures Scenarios (to 2080). OST/DTI, Environment Futures, Foresight, OST London <http://www.foresight.gov.uk/>."*

In summary: The project has demonstrated, across a range of catchment-coastal contexts, that an integrated natural science/social science modelling and assessment methodology can be both academically credible and policy relevant. The analyses differ in their complexity and comprehensiveness depending on the type of catchment studied and the availability and strengths of 'local' research teams. However, the main reason for the diversity present in the results and outcomes is a 'planned' one i.e. EuroCat set out deliberately to investigate different catchment-coastal situations both from a biogeochemical perspective and socio-economic and cultural perspectives. The overall project also aimed to test different evaluation methods e.g. cost-effectiveness, economic cost-benefit analysis and multi-criteria analysis. Across the spectrum of catchments all these objectives have been met, while allowing for more individualistic analysis within specific catchments in EU and accession economic and societal conditions.

In this report, highlights are presented to illustrate the approaches chosen in EuroCat and may serve as an appetizer for the detailed reports. Appendix I lists the key reports including the three volume European Synthesis Assessment of EuroCat.

3. Catchments and coastal regions definition: issues of scale

When the term "coastal zone" is used in general terms "coastal zone" basin managers, river scientists or environmental policy makers are actually including very small entities with much larger ones: from the Gulf of Trieste or the "Varna Lakes" to the Wadden Sea or the South Baltic.

In Table 1 the order of spatial scaling of the coastal zone entities in EuroCat are presented (Meybeck et al., 2004a).

Table 1 Spatial scales of coastal zone entities in EuroCat.

	1 st order	2 nd order	3 rd order	4 th order
Vistula	Vistula plume	Gdansk Bay	South Baltic	Baltic
Elbe	Elbe Estuary	German Bight	East North Sea	North Sea
Rhine	Rhine/Meuse delta		East North Sea	North Sea
Humber	Humber Estuary		West North Sea	North Sea
Seine	Seine Estuary	Baie de Seine	E. Channel	North Sea
Po	Po plume	NW Adriatic	North Adriatic	Adriatic
Idrija	Idrija plume	Trieste Gulf	North Adriatic	Adriatic
Axios	Axios plume	Thermaikos Gulf	NW Aegean	Aegean
Provadijska	Varna Lake	Varna Bay	NW Black Sea	Black Sea

The first order coastal zone is related to the immediate influence of the river. This is, typically what coastal geomorphologists have considered as an "estuary" which can be macro-tidal estuaries, rias or deltas and includes the river plume in the coastal zone. However the plume itself can be highly variable depending on the river discharge. A working definition could be the plume generally observed at the monthly average high flow. The seawater proportion in this entity ranges from 1 to 90%.



Figure 4 The Provadijska, Varna Lake and Bay system.

The second order coastal zone is related to the receiving coastal area, such as local bays or gulfs (Gdansk, Thermaïkos, Trieste, Varna). Its water is essentially composed of sea water (>90%) but may occasionally be diluted during very high floods. The influence of river material on sediments is still important. The zone is generally delineated by coastal morphology as slopes and undersea relief and may aggregate several first order entities, usually of similar types (e.g. macro-tidal estuaries, deltas are usually dominant).

The third order is related to portions of regional seas such as the Adriatic or even the North Adriatic, the Gulf of Finland, the English Channel. Few countries at this level usually share coastal waters, which is very important in terms of effective coastal management.

The fourth order refers to regional Seas. Basin to coast integration for management and regulations are also dependant on these scales.

The main issue for the first order level is the achievement of "hydro solidarity" within the basin, i.e. a full upstream/downstream integration of monitoring, stakeholder consultation, models and expert systems that can link basin pressures to transfers, across various administrative and/or political boundaries, and between the various land users, water users and other stakeholders.

For the second order coastal zones the targeted coastal domain should be clearly defined and delineated as for example the Bay of Gdansk or the Thermaïkos Bay. Local coastal uses and issues should be analysed, and links between coastal stakeholders and basin stakeholders should be made to established a basin to coast linkage. For each targeted coastal zone general models, which take into account all terrestrial inputs from various river basins and from direct sources, should be established to simulate the change of state of the coastal zone depending on net terrestrial inputs.

AxCat outcomes.

1. The Axios R. is the main contributor for Nitrogen (N) and Phosphorus (P) to the Thermaïkos Gulf, supplying 43% of N and 56% of P.
2. The most important N-emission pathways are: groundwater -45%, wastewater -29%, point sources -12%. The most important P-emission pathways are: point sources -64%, wastewater -20%.
3. P-emissions can be reduced by as much as 85%, if certain measures are undertaken (management of point sources and use of P-free detergents).
4. Improvement of the Thermaïkos Gulf by managing solely the Axios River nutrient emissions is not feasible. Other sources (minor rivers and point sources) should be managed as well.
5. Reduction of P-emissions from the Axios River will have a positive effect on the N/P ratio, which at present is <6, with positive influence on the biology.

Aris Kariagoris-AxCat

At the third order level the "coastal solidarity" idea may be embraced with common objectives for the use and state of the coast and its management. This requires also a full integration of coastal monitoring and river inputs databases across coastal geographic and political boundaries (e.g. North Adriatic, the South Baltic, or the Wadden Sea).

The regional sea level corresponds to the fourth order. For all European seas international treaties have long been established which take account of land based sources e.g. the Mediterranean. A "regional solidarity" is thus gradually developing. Many of these regional seas basins are not entirely located within the European continent, e.g. the Black

Sea and the Mediterranean Sea, or even within the future EU boundaries e.g. as the Arctic ocean and Black Sea which are essentially fed by rivers located in non EU countries. The regional solidarity (with its UN definition) should therefore go beyond those boundaries as well.

4. Modelling point and diffuse sources of nutrients in catchments

Within the EuroCat project two models were applied to estimate the point and diffuse sources of nutrients in catchments. For the Humber study estuary the applied model was Ecos (Cave et al., 2003b). For the other catchments (Axios, Elbe, Po, Provadijska, Rhine and Vistula) the model MONERIS was applied (Behrendt, 2004). Moneris has also been applied to other European river systems over the last years, these data are summarised together with those from the EuroCat catchments. This results in an European overview which covers 23 % (by area) of European catchments and 38 % of its population.

The MONERIS Model is designed to work with information collated from standard monitoring programs or available from federal bureaus and is based on:

- Data of river flow (from gauging stations);
- Water quality (nutrient concentrations from monitoring stations);
- Statistical data about nutrient inputs into the catchment;
- Geographical data (stored and analysed in a Geographic Information System (GIS)).

The point sources in Moneris are direct discharges and waste water treatment plant effluents; the diffuse source include atmospheric deposition, erosion, surface runoff, ground-water, tile drainage and paved urban areas (Figure 5).

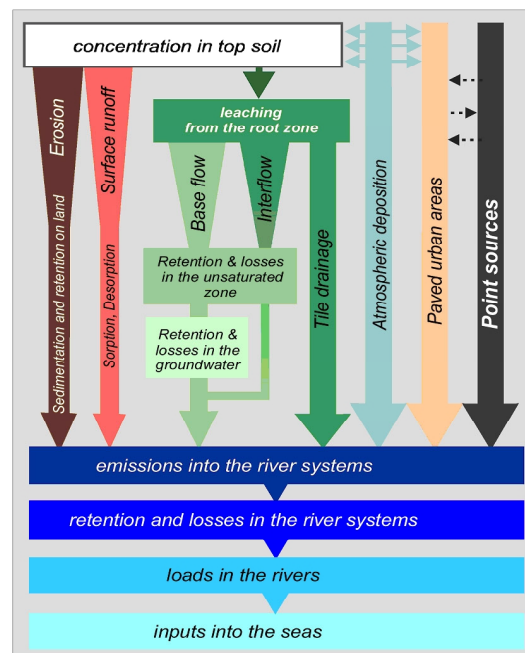


Figure 5 The MONERIS model structure.

Moneris estimates of annual load through of the diffuse and point sources as well as nutrient retention and loss within the river system itself (e.g. the stream's self-purification processes).

In the EuroCat study the highest share of point sources to total nitrogen emissions was found for the Provadijska catchment (75 %). This is due to very high nitrogen inputs into the river system from direct industrial discharges near Varna. For most other catchments the portion of point sources remained below 30%. Also catchments with high population density as Rhine and Po are characterized by point source inputs lower than 30%. Direct industrial discharges are high for the Provadijska. In the Vistula and Axios catchments only a small part of the population is connected to waste water treatment plants (WWTP's) and reflects a low discharge. A more detailed analysis showed that the efficiency of nitrogen treatment in wastewater treatment plants is higher in the north western European rivers compared with those in Eastern and Southern European rivers.

Figure 6 shows that major point sources for nitrogen are found in subcatchments with large cities. In general the nitrogen discharge from point sources is low for the larger river system. On the other hand, in smaller river systems like the Provadijska the N discharges from municipal wastewater treatment plants and direct industrial are very important. Also for the Odra and probably for the Vistula a further reduction of the nitrogen discharges from point sources can contribute to a substantial decrease of nitrogen input to the coastal zone.

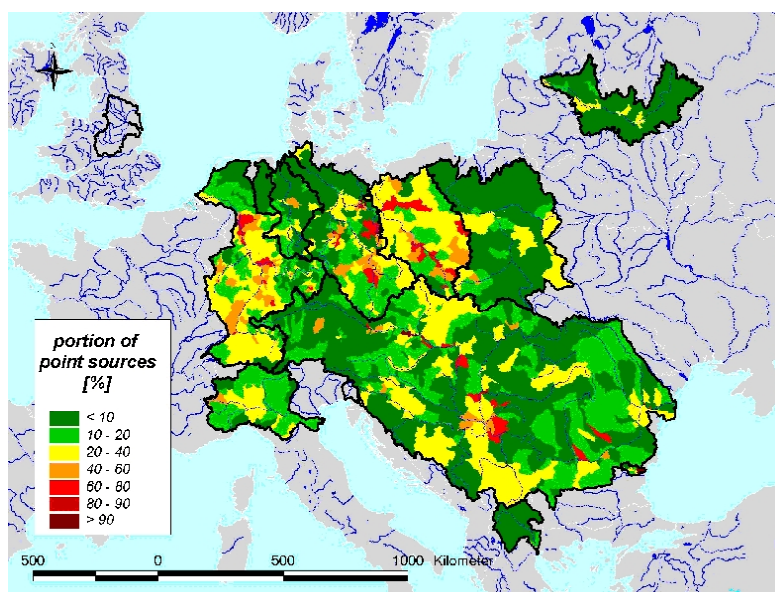


Figure 6 Point sources for nitrogen in % of total emissions.

Although the agricultural land use does not differ that much between the river systems studied, large differences have been found in nitrogen emissions. These differences reflect the intensity of the agriculture. Figure 7 shows that (with exception of the Povadijska) that overall agricultural activities are the dominant source for the nitrogen emissions into the river systems. Background emissions are low and vary between 8 and 24 % of the total. Water management strongly influences nutrient emissions to river systems. The short residence time of ground water in tile drained agricultural areas causes a low denitrification and higher nitrogen emissions are observed compared to undrained areas. The medium agricultural nitrogen emissions in some subcatchments of the Elbe, Odra and Vistula reflect this type of water management.

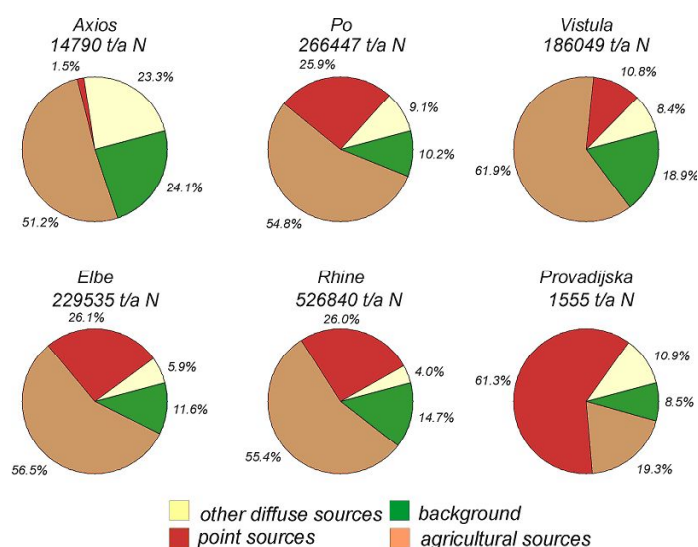


Figure 7 Different pathways of Nitrogen in EuroCat catchments.

Nitrogen retention varies strongly between the river catchments. Rivers with high specific flow and a minor area of lakes within the catchment, have in general lower N retention than rivers with a large number of lakes and low specific flow. For the total set of investigated catchments a mean N retention of 33% was found. The retention varies from 18 (Ems) to 86 % (Provadijska). Two large lakes in the catchment probably cause the high retention in the latter case. Also a high retention was observed in the Axios (61 %) due to temperate (higher denitrification) and the presence of medium sized reservoirs.

Other findings

The highest decrease in P-load to the coastal zone was achieved in catchments where P free detergents were implemented and the efficiency of wastewater treatment was improved (Rhine, Elbe).

Nitrogen removal in wastewater treatment plants (WWTP) was found to be the highest in Germany, Switzerland and the Netherlands. WWTP in catchments in Eastern und South-eastern Europe have a low removal efficiency. Often large cities do not possess wastewater treatment or have only treatment plants with a primary or secondary treatment.

The intensity of the land use especially in agriculture and the natural conditions influences the nutrient emissions much more than land use itself. This explains the high nitrogen emissions from the Humber rivers, Rhine and Po which are approx. two to three times as high as those found for eastern European river systems (Axios, Vistula, Provadijska, Odra, Danube, Daugava).

Large differences in flow conditions (surface & groundwater) and agricultural intensity cause extreme gradients in nitrogen loads from the catchments into the coastal zone. Whereas the specific nitrogen load from the Axios and the Vistula but also the Danube, Daugava and Odra into the coastal zone ranged between 2 and 6 kg/(ha·a) N, the corresponding loads in the Humber, Po and Rhine were three to four times higher.

For phosphorus point source (with the exceptions of the Elbe) are more important than diffuse sources. In the Axios and the Provadijska the contribution of direct industrial discharges is extraordinary high. In the Po, in contrast to other systems, emissions from

paved urban areas and people not connected to sewers and waste water treatment plants are the second dominant source. For all other river catchments the second largest source of P in the rivers are the agricultural emissions from erosion and surface runoff.

The scenario calculations shows clear that with the business as usual scenario a further reduction of the nutrient loads is not achieved. Policy target scenarios will achieve a substantial reduction in Eastern European Catchments only. Deep green scenarios will in most cases achieve OsparCom targets.

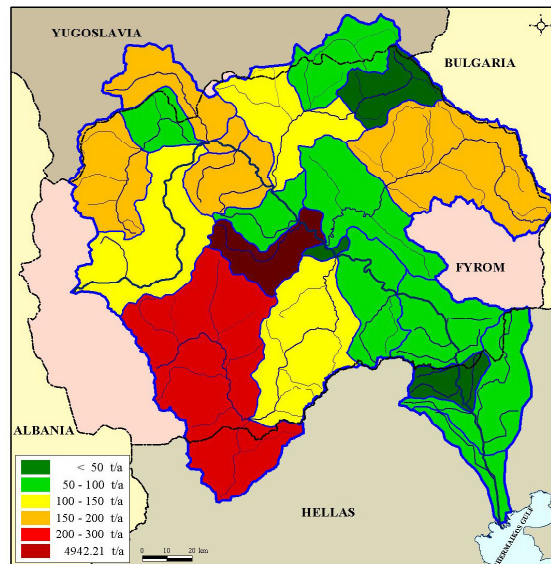


Figure 8 GIS presentation of pressures exerted by phosphorus emissions in the Axios catchment (Nikolaos et al., 2004b).

VisCat outcomes.

1. In two scenarios the costs of changes in the wastewater management and agriculture practices in the Polish part of the Vistula river basin (with 60% of Poland's population) amount to between EUR 6.8 billion and EUR 3.3 billion depending on the assumed rate of GDP and investment growth.
2. The main costs are associated with National Program of the Municipal Wastewater Treatment (NPMWT) - cost of building WWTPs and the system of sewerage in two scenarios - amount to EUR 5.0 billion in the Polish part of Vistula catchment,
3. In agriculture there are costs of infrastructure investments to implement the Nitrates Directive - EUR 1.8 billion in Polish part of Vistula catchment,
4. The reduction in biological productivity for the Policy targets low and high scenarios are about 7.0 %. These reductions are not very significant compared to the reductions of phosphorus and loads: depending on the scenario from 31 % for Policy target low scenario to 35 % for the Deep green scenario.
5. The Gulf of Gdansk water is still rich in nutrients and there is a exchange of matter with the Baltic Sea. A reduction of nutrient emissions will improve the state of surface waters in the Vistula catchment but it will not improve the state of the coastal zone in the Gulf of Gdansk.
6. To realise further reduction in the biological productivity longer time series and reductions in other sources of nutrients in the Balticare necessary. The policy targeting on the reduction of nutrients should not be limited to the single gulfs or bays but has to cover the whole catchment of the Baltic Sea.

Damian Panasiuk-VisCat

5. Scenarios and eutrophication modelling

Eutrophication of the coastal zone has been identified in the scoping analysis (EuroCat, 2004) as the main pressure on the coastal zone. In this highlight the translation of scenarios to inputs for coastal models is illustrated with results from VisCat and PoCat. A compilation of coastal modeling in EuroCat can be found in Kannen et al. (2004).

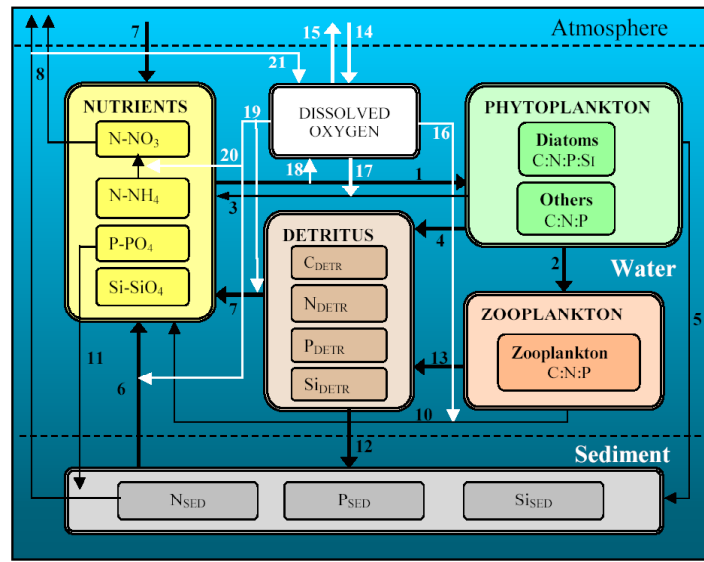


Figure 9 Scheme of the ProDemo model used for modelling eutrophication in the Bay of Gdansk and Baltic.

In the Vistula-Bay study (VisCat) three basic scenarios defining the rate of economic growth, population projections, agriculture policy as well as transport development have been considered in the assessment (Kowalewski et al., 2003).

1. Policy targets - high scenario. This scenario assumes 5-6% increase in the GDP rate in 2004-2020. The high rate of economic growth enables the realization of the National Program of Municipal Wastewater Treatment (according to Directive 91/271/EEC). There is a 75% reduction of the discharged nutrient loads in Polish agglomerations above 2000 p.e. A 1% growth of the population in years 2000-2015 is expected. There will also be a 20% rise in migrations to the cities. In agriculture policy application of the Code of the Good Agriculture Practise limits uncontrolled pollution of the environment by natural fertilizers (manure), but the use of mineral fertilizers increases.
2. Policy targets – low scenario. This scenario assumes a lower economic growth between 2 and 4% in 2004-2020. Hence it is not possible to fully implement the National Program of Municipal Wastewater Treatment (according to Directive 91/271/EEC). Wastewater treatments to be constructed by 2010 will be on line by the end of 2015. Agricultural policy causes the storage of manure to remain unimproved, but at the same time the use of mineral fertilizers is not increasing either.

3. Deep green scenario. This scenario accomplishes all the objectives of the scenario Policy Targets concerning construction of wastewater treatment plants. Laundry detergents with phosphates are removed from the market. Good Agricultural Practice is introduced and the use of mineral fertilizers is decreasing.

The reduction of river input of total nitrogen in three evaluated scenarios is rather small. However, the reductions of phosphorus loads from rivers are much larger (from 30.5 % for Policy target low scenario to 34.7 % for Deep green scenario), which affects the growth of phytoplankton.

As an example of the many modelling results the N/P distribution for the scenarios is shown in Figure 10. The distribution of the N/P ratio has been calculated to analyse the potential limiting conditions (winter conditions) and the real limiting condition under the intensive growth of phytoplankton (summer time). It has been observed that in the reference year 2002, which represents recent biogeochemical conditions, the nitrogen is limiting nutrient in the large part of the Gulf of Gdańsk ($N/P < 16$), whereas in all scenarios in 2015 year phosphorus limits the growth of phytoplankton in whole Gulf ($N/P > 16$). Therefore, there is much less inorganic nitrogen during summer in reference year 2002 than at the same time of the year during the scenarios projections. The distributions of phosphorus are opposite.

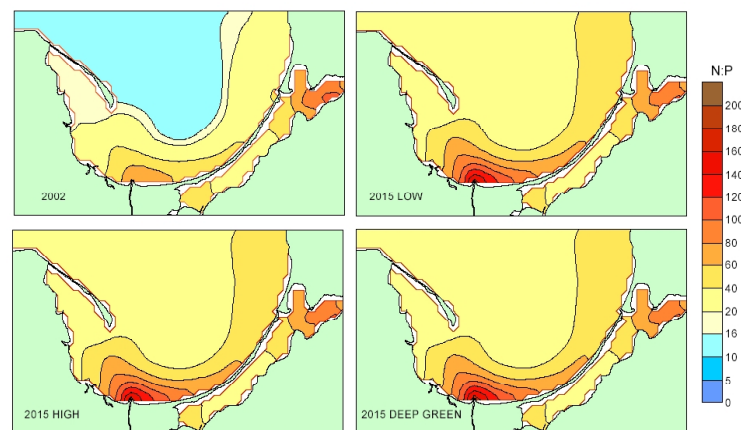


Figure 10 Nitrogen/phosphorus ratios in the Bay of Gdansk for various scenarios.

Primary production depends on three basic factors: nutrient availability, solar radiation and the water temperature. There is a general tendency: the further from the land towards the open sea, the lower the rate of the primary production. The values for the central part of the Gulf of Gdańsk are almost half the values in the Eastern part of the Gulf. The rate of primary production in the open waters of the Gulf of Gdańsk does not vary significantly among the scenarios, so this part of the Gulf is less sensitive to changes in nutrients. The areas with most visible difference between the reference year 2002 and the Policy targets high scenario are located to the North of the Vistula River outlet and along the Hel Peninsula. The loads of the nitrogen and phosphorus by the Vistula River have a strong direct impact on the rates of primary production.

N:P ratios in river waters and consequently in the sea water determine competitive interactions among plankton algal taxa. If nitrogen is the limiting nutrient then the reduction

of phosphorus loads may not cause any reduction in primary production unless the reduction reaches a certain level ($N:P=16$). Below this value phosphorus is generally thought to be the growth of phytoplankton.

In summary: The reduction of total nitrogen load to the Gulf of Gdańsk ranges from 9 % for the Policy target low scenario to 10 % for Deep Green scenario. The reduction of total phosphorus load is much larger: from 41 % for the Policy target low scenario to 46 % for the Deep green scenario. Even though scenarios vary in terms of assumptions (economic development, agriculture policy), they do not vary significantly in respect of the total nitrogen and total phosphorus discharged to the Gulf of Gdańsk: the differences in nitrogen loads can be neglected, while the differences in phosphorus loads are rather small. These conclusions highlight the complexity of the impact of the catchments inputs on the Gulf of Gdańsk. The coastal waters are biologically the most productive areas of the Gulf of Gdańsk and include recreational areas along the beaches in Gdańsk and along the Vistula Lagoon. The scenarios showed that the reduction of primary production rate in these areas is rather low. Because the reduction of phosphorus loads is much higher (more than 40 %) than nitrogen loads (less than 10 %) phosphorus became a limiting nutrient in the Gulf of Gdańsk. Further reduction of phosphorus load should lead to the reduction of biological productivity in the Gulf of Gdańsk.

Eutrophication is also considered to be the most important impact of the Po Catchment on the North Adriatic Coastal zone (PoCat) and is caused by nutrients loads discharged by the river (Artioli et al., 2004). With this focus, a dynamic water quality model has been implemented.

The Coastal Zone affected by the Po river discharge has been defined on the basis of salinity variability pattern (Figure 11). Subsequently the EPA water quality model WASP6 was implemented. WASP6 proved to be linked easily with the model applied on the catchment (MONERIS) and the locally developed coastal zone model.

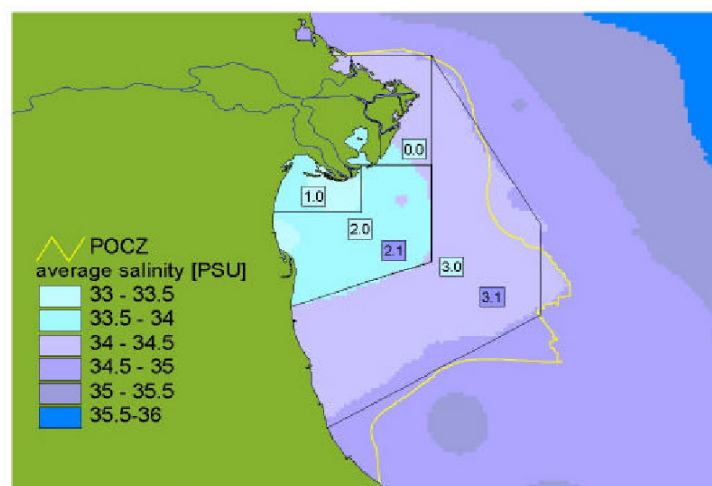


Figure 11 Compartmentalization of the POCAT CZ in 6 segments: 4 surface segment (0.0, 1.0, 2.0, 3.0) and 2 subsurface (2.1, 3.1).

The output of WASP6 allows to calculate daily TRIX values, the trophic state index used in the Italian legislative framework. This index summarizes the different factors typical

of the eutrophication: the productivity factors (concentration of Chlorophyll-a and the Dissolved Oxygen as absolute deviance from saturation) and nutritional factors (concentration of Dissolved Inorganic Nitrogen and Total Phosphorus). Numerically the index is scaled from 0 to 10, covering a wide range of trophic conditions from oligotrophy to eutrophy. The scale is divided into four classes as shown in Table 2.

Table 2 Classification of the trophic state of Coastal waters.

TRIX	Trophic State
2-4	Good and Above
4-5	Moderate
5-6	Poor
6-8	Bad

Using this classification, the current average trophic state of the PoCat CZ is poor (TRIX>5). During the year the CZ trophic state can vary from moderate (in summer and far from the Po delta) to bad (near the river mouth during winter and autumn).

The variability of eutrophication processes during the year is high in the coastal zone. Evaluating the coastal zone trophic state only on the basis of the yearly average TRIX would miss critical eutrophication phenomenon that may occur during the year. For this reason an evaluation of eutrophic risk has been carried out. The indicator eutrophic risk has been defined as the probability that daily TRIX value are higher than the lowest limit of the trophic state poor (TRIX=5) or bad (TRIX=6).

The run of two sets of hypothetical Coastal Zone scenarios (with simple percent variation of nutrient input) has shown that the Po also has a major influence on the North Adriatic Sea. As in the Bay of Gdansk, the Adriatic Coastal Zone has a strong resistance to change in its trophic state: only with a great reduction of nutrient loads it is possible to reach a good trophic state (TRIX<4).

Table 3 Eutrophic risk indifferent scenarios: in the table are shown the probabilities (%) that the TRIX values in the segment (or in the whole POCAT CZ) are higher than 5 (poor trophic state).

	Seg # 1			Seg # 2			Seg # 3			CZ		
Scenario	2001	2208	2016	2001	2008	2016	2001	2008	2016	2001	2008	2016
BAU	94	94	94	74	74	76	49	49	51	58	58	60
PT	94	94	90	71	71	58	46	46	36	55	55	43
DG	94	94	88	69	69	53	45	45	33	54	54	40

In the second set of scenarios (Table 3), the coastal zone model has been used in conjunction with MONERIS applied to the Po catchment, to estimate the impacts of the anthropic activities in the catchment on coastal zone at 2008 and 2016.

In the options considered in the Policy Targets and Deep Green scenarios, the average trophic state of the Coastal Zone improves from poor status to moderate status (TRIX between 4 and 5) but the area closest to the Po delta will still have a high probability (about 40%) to exhibit critical eutrophication phenomena (TRIX>6).

Over all, Kannen (2004) reports that the Bay of Gdansk, parts of the North Sea and the Thermaïkos Gulf all showed strong resistance to ecosystem change, despite the strict loading reductions of the Deep Green scenarios.



Figure 12 Mucilage (recurring micro-algal blooms) in the Adriatic Sea.

6. Evaluation of management options and the role of policy advisory boards

In each of the regional catchment-coast studies a “Policy and Stakeholder Advisory Board” was set up to ensure their input in the study. Their roles in EuroCat is highlighted with results from the RebCat study (Lise et al., 2004). More details, including approaches from the other catchments can be found in Turner (2004) and in Ledoux and Turner (2003a).

RebCat is the case study which assessed nutrient abatement in the Rhine and Elbe catchments and its impacts on the North and Wadden Seas. The research question which RebCat addressed was whether the costs of nutrient abatement in catchments would be compensated for benefits to coastal ecosystems and their users.

The steps in the analysis, and interactions with this board, are shown in Figure 13. The PAB comprised potential end-users (e.g. representatives from the International Rhine Commission and from Dutch and German ministries) as well as other stakeholders (e.g. representative of agricultural and recreational sectors, environmental NGOs). Interaction with the PAB occurred via two rounds of interviews. The first round of interviews asked questions about the policy context of the case study, future scenarios, the viability of measures which would abate nutrient emissions from the catchments, the objectives of management for the North and Wadden Seas, and the institutional framework within which management occurs. Specific information gleaned from the PAB included: 1) input to the economic CENER model (Lise, 2003), which undertook a cost-effectiveness analysis to identify the cheapest means of abating nutrients, and; 2) evaluation criteria and their weights for a multi-criteria analysis (MCA), which compared and ranked alternative means of achieving nutrient reduction targets.

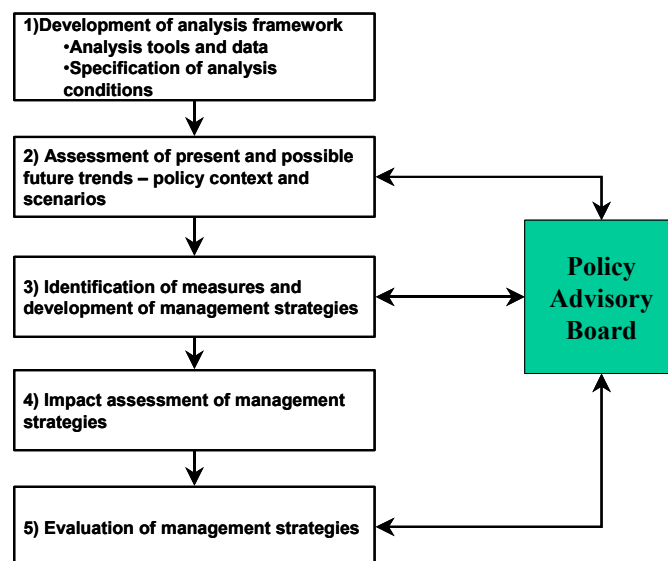


Figure 13 The steps in the Multi Criteria Analysis (MCA) and interaction with the Policy Advisory Board.

The second round of interviews presented board members with the project's results. They were asked for their reactions, and to re-evaluate their earlier responses. The following conclusions were drawn from the two interviews.

1. Interviewees did not see the nutrient problem as a major, present problem in coastal areas. However they were aware that nutrient loads are leading to various symptoms of eutrophication. It was generally agreed that the main sources of nutrients are agriculture and wastewater treatment plants.
2. There was also agreement that tourism, recreation, fisheries and organisations concerned with nature are the main affected parties of river nutrient loads, and so the main beneficiaries of load reduction and improved coastal quality. Difficulties in understanding the severity of impacts, seeking compromises and conciliating differences in interests were highlighted.
3. The first interview with PAB members emphasised that water institutions were not designed to solve problems but to divide jurisdictions and responsibilities. When confronted with the role of river loads in coastal eutrophication, this division serves to limit the effectiveness of any policy designed to address the problem.
4. PAB members were not in agreement about whether and to what extent nutrients need to be abated. The results showed that rigorous measures would be needed to achieve current policy targets.
5. The analysis also showed that the creation of wetlands in catchments is a potentially promising measure which would reduce the costs of nutrient abatement. However Dutch PAB members emphasised that this would need to occur upstream in the Rhine catchment, as the lack of available land would constrain wetland construction in the Netherlands.

The second round of interviews presented PAB members with the results of the multi-criteria analysis. MCA was used because management objectives and evaluation criteria lead to a mixture of monetary and non-monetary information about policy alternatives. Evaluation criteria are grouped into three categories. Criteria include the cost of taking reduction measures (calculated with CENER as presented in Table 4), changes in fish catch and coastal tourism (derived via literature and expert judgement), various indicators for coastal ecology (calculated with ERSEM), recreational coastal amenity and wetland non-use amenity value (calculated via value transfer from a meta regression model and CENER), unemployment and sectoral transition (derived via literature and expert judgement).

The MCA ranked five policy alternatives for nutrient reduction, namely: the business-as-usual alternative (BAU); medium reduction (MR); strong (SR) reduction; medium reduction with high retention (MRHR); and strong reduction with high retention (SRHR). The last two alternatives included the possibility of constructing nutrient retention basins and dams in the catchment. The base information for the MCA is an effects table, as shown in Table 4 for the River Rhine.

The outcome of the MCA, conducted using the DEFINITE software, is shown for the Rhine-Coastal system (results for the Elbe were similar). The overall result in Figure 14 is based on equal weights for the three evaluation categories, to which most PAB members had agreed during the first round of interviews.

Table 4 MCA-effects table comparing effects of 5 policy options on the impact of river Rhine discharge on the receiving North Sea. For further details, refer to Lise et al (2004).

		Policy options					
	C/B*	Unit	BAU	MRHR	MR	SRHR	SR
<i>Economic</i>							
Cost (total)	C	ME	816	1041	1237	1892	3022
Fish catch		--/++	++	+	+	0	0
Coastal tourism		--/++	0	+	+	++	++
<i>Environmental</i>							
Primary production	C	mmol m ⁻³ y ⁻¹	259	256	256	253	253
biodiversity	B	scale [0-1]	0.37	0.38	0.38	0.38	0.38
Cycling-N	B	y ⁻¹	3.9	3.9	3.9	4.1	4.1
Cycling-P	B	y ⁻¹	6.7	6.7	6.7	6.8	6.8
Storage capacity-N	C	mmol m ⁻³ y ⁻¹	55.9	57.0	57.0	-3.1	-3.1
Storage capacity-P	C	mmol m ⁻³ y ⁻¹	0.4	0.4	0.4	0.4	0.4
Matter losses-N	C	mmol m ⁻³ y ⁻¹	423.8	412.4			
Matter losses-P	C	mmol m ⁻³ y ⁻¹	14.0	13.8	13.8	13.7	13.7
<i>Social</i>							
recreational amenity	B	ME	20	34.6	34.6	50.2	50.2
wetland amenity	B	ME	0	62.8	0	190.0	0
Unemployment	C	%	7.4	6.9	6.9	7.2	7.2
sectoral transition		--/++	++	+	-	0	--

* C/B = cost or benefit criterion. A cost criterion has large values indicating 'bad', large values for benefit criteria indicate 'good'.

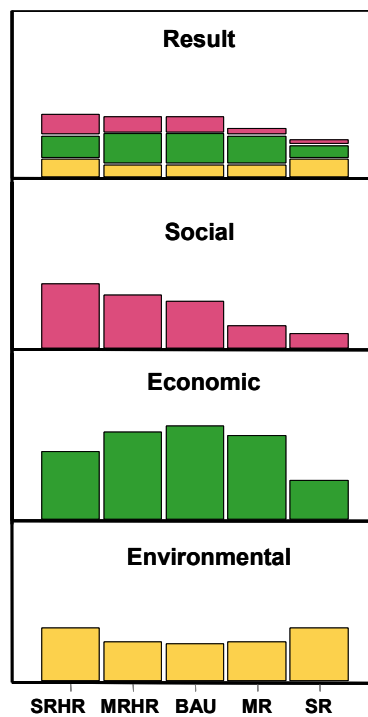


Figure 14 Scoring of MCA for different scenarios (see text for explanation) and the combination with equal weighting of Social, Economic and Environmental.

The MCA shows that the strong reduction alternative with the possibility of constructing high nutrient retention basins and dams in the catchment (SRHR) is the highest ranked alternative. The medium reduction with high retention (MRHR) and business-as-usual (BAU) are a close second and third. The ranking is very sensitive to the weight assigned to the economic category. Small increases in this weight change which of these three options ranks highest. When confronted with these results, PAB members reconfirmed their earlier view regarding the weights assigned to evaluation criteria and categories.

In Summary: RebCat's interaction with its PAB showed that there is an inadequate understanding among stakeholders of catchment influences on the coast. This situation is complicated by multiple jurisdictions, which constrain the development of relevant and effective policy. A comprehensive vision is needed of how agricultural and water management sectors should develop in the future.

At a more specific management level, the analysis concludes that there is little to distinguish the SRHR, MRHR and BAU policy options. PAB members generally agreed with this conclusion, which raises two further issues. The first is whether current policy targets for reductions of nutrient loads in the Rhine and Elbe are too severe. The good performance of BAU, particularly if a higher emphasis is placed on economic evaluation criteria, prompts this question. The second issue is that, if nutrients are to be abated, retention schemes provide a measure which is both cheap and effective. The question is then how and where to place dams and retention basins throughout catchments to optimise their nutrient uptake.

7. Coastal realignment, nutrient reduction and cost-benefit analysis

While for the wider EuroCat project, scenarios are based largely on economic and social changes in the catchments, in the case of the Humber, the focus has been on the estuary (Cave et al., 2003b). Managed realignment of hard defences along the estuary and tidal rivers (the setting back or other changes in sea and flood defences) is likely to play an important part in future activities around the estuary, and both its socio-economic and water quality impacts, must be taken into account in any future scenarios. The Humber Estuary is an example of a post-industrial estuary. It has been massively modified over the last centuries both in terms of chemical inputs and its physical structure. More than 90% of the total wetland habitat within the estuarine system has been lost to reclamation over the last 300 years or so and with this process some habitats such as freshwater bogs and wetland forests have been completely eliminated, while others such as salt marshes were greatly reduced in area. In terms of chemical inputs, the area has long been subject of human activities, indeed the catchment is the cradle of much of the UK Industrial Revolution. Mining has gone on since Roman times and the waste spoil from this activity still dominate the fluxes of some metals within the catchment. In the twentieth century the estuary shoreline itself was developed with intense industrialisation and port development including metal smelting activity. Much of this heavy industry has now gone, though a vibrant petrochemical industry remains. However, the sediments retain the history of the smelting and other industrial activity. Over the last two hundred years the catchment population has grown dramatically increasing waste discharges and intensification of agriculture has dramatically increased. Coastal realignment aims at restoring part of the former landscape with its extensive wetlands.

Reducing the concentrations of nutrients in river waters only (BAU), results in an average 15% reduction in ammonia in the inner estuary, and an average 14% reduction in the middle part of estuary. Ammonia is almost all used up or converted to nitrate before reaching the outer estuary. Nitrate concentrations in the inner and middle parts of the estuary are reduced by an average of 11%, while average concentrations in the outer estuary are reduced by 9%. Dissolved phosphorus is reduced by an average of 11% in the inner estuary and 18% in the middle estuary, but is increased by an average of 14% in the outer estuary. Total phosphorus however is reduced by an average 6% in the inner estuary and 4% in the middle estuary, but shows no significant change compared to average baseline in the outer estuary, reflecting the buffering capacity of sediment-bound phosphorus due to the natural high turbidity of the estuary.

The PT scenario includes a 20% reduction in inputs of nutrients from point sources in the tidal rivers and estuary, and an increase of 1321 ha in the intertidal area of the estuary, as well as the reductions in inputs from the rivers discussed above. Adding on the reduction of inputs from point sources to the lower river concentrations leads to a much greater reduction in concentrations of ammonia in the inner and middle estuary (26% and 21% respectively), but has no significant effect on P or nitrate in the estuary. Increasing the intertidal area of the estuary further reduces the ammonia, by an average of 32% of the baseline concentrations, due to the increase in area for nitrification of ammonia to ni-

trate. The increase in intertidal area in the model leads to an increase in the amount of sediment available for interaction with the water column, thus buffering and in some instances possibly increasing the total P concentrations in the water.

Scenarios in the Humber regional study.

1. Business as Usual Scenario

For the Business As Usual scenario, it is assumed that the nutrient and trace metal flows from the rivers will remain similar to those for the 1993-2001 period, until 2025. This assumption is made because the increases in nutrient and contaminant loads estimated to be generated by population growth over this time period are small compared with the inherent variability of inputs from the river catchment to the estuary, and are assumed to be balanced by the current ongoing upgrading of sewage treatment works. For the tidal rivers and estuary, significant upgrading of sewage treatment works has taken place in the last few years, and these improvements are included in the BAU scenario.

2. Policy Targets Scenario

This scenario assumes that there will be a reduction in inputs of nutrients and contaminants, in line with reductions expected from the full implementation of the Urban Waste Water Treatment Directive, and the designation of almost the entire Humber catchment as a Nitrate Vulnerable Zone, in compliance with the Nitrates Directive. It also assumes that the strategy of managed realignment of sea defences around the estuary already beginning to be implemented by the Environment Agency, will be fully realised, increasing the current intertidal area of the estuary by 1321 ha.

3. Deep Green Scenario

This scenario assumes significant reductions in inputs of nutrients and contaminants to water-courses, as for the Policy Targets scenario, and widespread adoption of managed realignment as a flood defence policy, leading to an increase in intertidal area along the estuary and tidal rivers of 7494 ha.

The DG scenario includes large changes to the intertidal zone in the tidal rivers and estuary, resulting from extensive setback of flood defences along the banks. In the case of the tidal rivers, this can mean doubling the width of the river at certain points compared to its current morphology, with knock-on effects on nutrient cycling and sediment transport.

The DG scenario has the same reductions in inputs of nutrients from the rivers as the PT scenario. In addition, there is a 50% reduction in inputs from point sources in the tidal rivers and estuary, and extensive increases to the intertidal zone, both around the estuary and in the tidal reaches of the rivers. If river reductions and the reduction in point source inputs are taken into account only, i.e. no managed realignment takes place, then the reduction in concentration of ammonia in the inner and middle estuary of an average of 40% and 31% respectively, exceeds that for the full PT scenario. Average reduction in nitrate concentrations of 13% (inner) and 14% (middle) are similar to that for the PT scenario, while the average 13% reduction in ammonia concentrations for the outer estuary is slightly better than the average of 10% reduction achieved in the full PT scenario. Thus it appears that reducing the point source inputs by 50% lowers nutrient concentrations in the estuary to a greater extent than the combination of 20% point source reduction and 1321 ha increase in intertidal area.

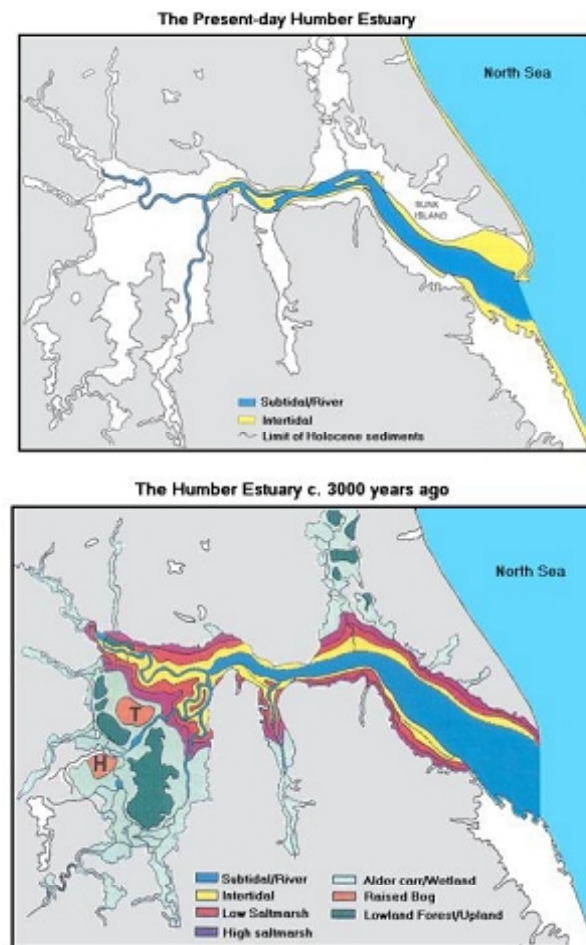


Figure 15 The current Humber estuary and the estuary about 3000 years ago.

The final step in achieving the full DG scenario is implementing the extensive managed realignment, resulting in an overall increase in intertidal area throughout the tidal rivers and estuary of 7494 ha. Adding this step has an enormous effect on nutrient concentrations in the estuary. Average ammonia concentrations are reduced by 87% compared to baseline in the inner estuary, and by 67% in the middle estuary. Average nitrate concentrations are reduced by 26% (inner) 30% (middle) and 25% (outer) compared to the baseline. Average dissolved-P is reduced by 55% (inner) and 76% (middle) although increased by an average of 22% over the baseline concentrations in the outer estuary. Average total-P concentrations are reduced by 13% (inner) and 12% (middle), while no change in total-P concentrations are recorded in the outer estuary compared to the baseline scenario.

Implementation of the extensive managed realignment envisaged for the DG scenario, without the reductions in inputs from the rivers or point sources, was found to still lead to significant reductions in nutrients in the estuary.

In summary, the combination of point source reduction and managed realignment are the most effective at reducing ammonia concentrations in the estuary. Point source reduction has no noticeable effect on nitrate concentrations, but reducing river inputs is effective.

A small increase in intertidal area is effective in removing ammonia, but not in removing nitrate, as it is buffered by the nitrification of ammonia. However, extensive increases in intertidal area are effective in reducing nitrate concentrations, comparable to the effect of reductions in the riverine inputs. Reductions in riverine input are reasonably effective in reducing the concentrations of dissolved-P in the estuary, but the effect is not significantly enhanced by point source reduction. Small amounts of managed realignment have very little effect on P concentrations, but extensive realignment is very effective at reducing dissolved-P and reasonably effective at reducing concentrations of total-P in the inner and middle estuaries.

Given the findings reported above, an economic cost-benefit analysis has been undertaken to test the proposition that compared to traditional sea defence and coastal protection schemes ('hold the line' hard engineering works) managed realignment is an economically efficient policy option. Further, the modelling results show that managed realignment schemes can also generate additional environmental benefits. The analysis therefore takes as a core starting assumption that coastal managed realignment policy will be an important component of any future planning for the Humber estuary and catchment. But the key insight is that managed realignment (and its impact in terms of increased intertidal habitat) carries with it a number of positive externality effects. It creates more habitat with potential biodiversity, amenity and recreational values; a more extensive nutrient and contaminants storage capacity; and a carbon sequestration function. All these potential economic benefits are in addition to its sea defence/coastal protection benefits in terms of increased flexibility in response to sea level rise and climate change and therefore reduced maintenance costs.



Figure 16 Photographic impression of the Humber estuary.

From an economic efficiency perspective, the first test of managed realignment requires the scheme or programme to demonstrate net economic benefit i.e. that compared to the traditional hard engineering sea defence strategy managed realignment yields an efficiency gain in terms of net benefit or lower overall costs. The analysis demonstrates that for a range of managed realignment schemes around the estuary and the tidal rivers, there is a net economic benefit i.e. that the costs of realignment over a 25 year time period or more are outweighed by the benefits created in terms of savings in maintenance costs and the positive environmental externality effects.

Coastal realignment can therefore form a key component of, for example, any wider catchment or estuary water quality policy. Cost-effectiveness analysis can show which combination of policy measures combined with realignment are most economic. Thus achieving higher water quality standards in the Humber estuary in terms of nutrient reduction will require managed realignment plus a set of measures directed at point sources e.g. sewage treatment plants and diffuse pollution e.g. agricultural run-off. Since managed realignment policy will be implemented anyway, and our analysis shows that it is an economically efficient strategy, the pragmatic response to water quality issues should be to factor in this policy context. Therefore the policy response to the problem of meeting future higher water quality standards should be to find the most cost-effective set of measures around the estuary and in the catchment that can provide additional nutrient reduction effects, once the baseline effect of increased intertidal habitat (via realignment) has been quantified. The analysis has investigated improved sewage treatment and nitrate zoning and related measures in agricultural areas as elements of the overall pollution reduction programme, given a range of water quality targets in the estuary.

The main findings were as follows:

- Managed realignment, if implemented on a reasonably large scale, could be an effective way of improving the water quality of the Humber estuary. In the scenarios outlined above, farming practices throughout the more than 25,000 km² of the catchment would have to be radically changed in order to achieve reductions in concentrations of nutrients throughout the estuary comparable to those realised by creating 75 km² of new intertidal area around the estuary and tidal rivers by realignment of flood defences.

Calculations of inputs to the North Sea from the Humber estuary (and all estuaries entering the North Sea), which are currently based on inputs as per OSPAR guidelines, should be revised to take account of the transformations that occur within estuaries and tidal rivers, if an accurate assessment of inputs to the North Sea is to be made.

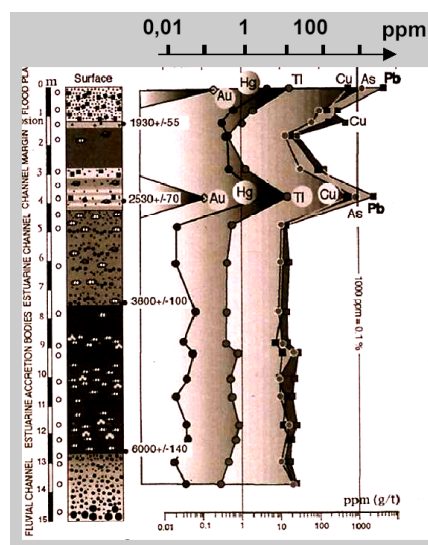
- Measures to tackle diffuse nutrient pollution from agriculture (such as those implemented in NVZ designated areas) are more cost-effective than upgrading/construction of tertiary treatment at STWs. This is particularly the case for nitrogen and may also apply to phosphorus.
- Managed realignment has a number of environmental benefits (habitat creation, carbon sequestration, etc) the value of which can more than offset of the costs associated with this option and can result in substantial positive net present values.

8. The heritage of past pollution (hot spots) in catchments

European catchments have been active sites of mining and industrialisation over past centuries. Mining activities go back to at least Roman times. Remnants of mining activities may still be found in catchments in the form of tailings and other polluted areas that are still present. In addition, the last 100 years of industrialisation (with no pollution control) has resulted in further contaminated areas (hotspots). This heritage of past pollution and long industrial development is present in the Vistula, Humber, Rhine and Idrijca. In the case of the Vistula, extensive damming has prevented the contaminants from reaching the coast. In the case of the Rhine, there are still elevated levels of PCBs in sediments reaching the Rhine estuary, despite the banning of PCBs (used in hydraulic equipment in mining) more than 20 years ago. HCB contaminated sediments in the Rhine catchments, which are trapped behind dams cannot be considered as permanently stored. These "hot spots" and diffuse sources in catchments are amenable to erosion and slow release. A similar situation exists in the Humber.

Rio Tinto mining.

The Rio Tinto basin in South West Spain has been mined by prehistoric societies some 4500 years ago. The impact of this activity is perfectly preserved in estuarine cores (see figure). Natural background levels of Au, Hg, Tl, Cu, As and Pb are relatively stable from 6 000 BP to about 2700 BC, i.e. they have not been affected by climate variability; At 2550 before Christ metals contents had increased 50 to 200 times, and then decreased. However content scale in logarithm background values have not returned to pristine values, particularly for Hg which remained more than 10 times higher. A second mining period is noted some 500 years later in this core (Golden ornaments corresponding to these periods can be seen at the Lisboa archaeological museum). The Rio Tinto Ore district has been continuously mined since this period for Au, Pb and others. Inherited contamination and present mining impact are very closely related in this region where the concept of reference state is very difficult to apply.



This issue of the legacy of past pollution in catchments was addressed in EuroCat through a case study in the Idrijca catchment (Slovenia) which bears similarities to other

areas including the Rio Tinto Basin in Spain (see box). In the case of the Idrijca the concern is mercury mining (Horvat, 2004).

Mercury is toxic and in the past it was mostly people in direct contact with inorganic mercury that were affected such as miners and hatters. The awareness of the toxicity of monomethyl-mercury (MMHg) is recent. This species was identified some 50 years ago as being generated microbiologically in Hg-contaminated sediments accumulating in the food chain leading to toxicity of human food.

The Idrijca region hosts the world's second largest mercury mine which has been active for more than 500 years. Mercury pollution is still very high, despite the fact that the production was minimized some 10 years ago and that the mine will be closed in a few years. During the years of refining and smelting, about 37,000 tons of mercury have been lost in the environment; soil and river sediments in the wider Idrijca region are highly polluted. Relatively high quantities of mercury-polluted material have found their final destination in the Gulf of Trieste, some 80 km away from the mine. The mass balance for the Gulf has shown that about 1.5 tons of mercury is being washed to the Gulf of Trieste every year.

Past studies were mostly oriented towards estimating concentrations of mercury in terrestrial and aquatic environment (soil, water, river sediments), and also towards evaluating of transport pathways and the transformation of mercury through the air and aquatic environment. These studies did not examine different scenarios and mostly did not consider the whole catchment and so were not of great help for decision-makers. IdriCat has made a substantial step to redress this situation. Although the Italian part of catchment and the Gulf of Trieste could not be modelled due to lack of input data and uncertainties about the marine environment, IdriCat has resulted in several findings which are relevant for decision makers. Decision makers formed part of the Policy Advisory Board of IdriCat.



Figure 17 Idrijca landscape prone to erosion.

From the data on Hg concentrations in the catchment it is clear that measures for reducing accumulation of Hg in the Gulf of Trieste should be focused on preventing "movement" of Hg by soil erosion. Another focus is prevention of methylation of Hg. Since methylation is linked to the presence of organic matter this could be achieved by preventing organic pollution of the rivers Soča, Idrijca and Vipava. Hence, in operational terms these two sets of measures are associated with:

- Geology, climate, lithology, topography, soil characteristics, land cover, land use, etc. (as regard soil erosion);
- Urbanisation, industrial activities, agriculture, environmental infrastructure (particularly wastewater treatment plants), etc. (as regard organic pollution of the rivers).

GIS modelling was used as a basis for evaluation of erosion susceptibility in the catchment. When combining this with data on surface water quality (river sections of highest organic pollution), areas where the measures are expected to give best results are identified.

Since geology, climate, lithology, topography, soil characteristics (listed above as determinants of soil erosion) cannot be influenced by man (and certainly not in the context of this project) land use, urbanisation, industrial activities, agriculture and environmental infrastructure are considered for the purpose of specifying the measures. In this sense scenarios focused on future development paths for the region. Agriculture deserves special consideration since it affects the erodibility of soils.

Erosion modelling focused on the expected reduction of Hg emissions due to elimination of hot spots and reduction of erosion potential. The GIS based erosion model for IdriCat was developed as a part of the Hg-mass balance model for the catchment and coastal sea.

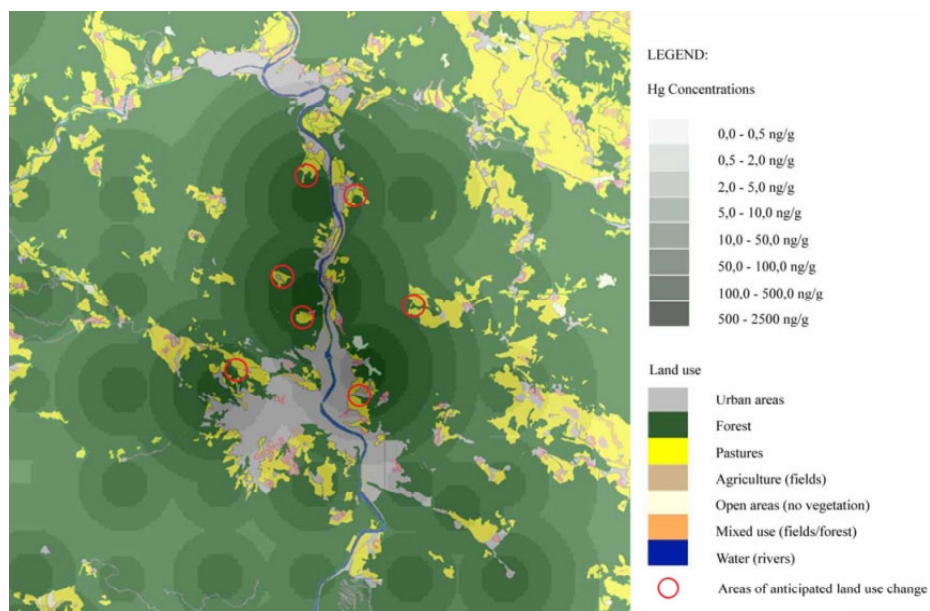


Figure 18 Land use and mercury concentrations in the Idrijca region.

The graphic image of the model from the Hg release with soil erosion (Figure 18) for the municipality of Idrijca shows a high level of homogeneity with exception of the so-

called hot spots on the outskirts of Idrijca (former mercury mine facilities in northern, eastern and south-western part of the town). Average Hg concentrations in soil at these locations are between 500 and 2000 ng/g. Mercury release from “hot spots” represents the main mercury input into the Idrijca/Soca river system and the Gulf of Trieste.

ProvaCat outcomes.

1. Finding that the observed trends of the regional economic development are carrying huge risk of degradation of the natural capital -- they can lead to irreversible negative after-effects on the entire ecosystems (the rivers, lakes, the coast and the sea).
2. The SWOT Analysis done for the economic structure and development of Provadijska catchment area (strong sides - weak sides) provides the necessary ground for drawing up consistent decisions and forecasts.
3. Providing reliable and understandable information to policy makers about the economic, social and ecological after-effects of the development of the regions
4. Forecasting different possible scenario of development, which determines different economic, social and ecological policy.
5. The opportunity to work in collaboration with the other participants gave the possibility of comparing the socio-economic and ecological problems in different areas and countries and from here on to outlined their specific and common features.

Stovan Totev-ProvaCat

The first step in scenarios development was the identification of the main sources of Hg emissions, determination of Hg concentrations in environmental media, as well as modes of its transport and accumulation along the catchment. The second considers possible (alternative) measures to prevent these emissions, reduce Hg concentrations and avoid its transport in the catchment to determine the ultimate accumulation in the coastal sea. Measures for reducing health risk were also considered to be important. Comparative evaluation of the alternatives which includes multi-criteria, cost-benefit, cost-effectiveness analysis, strategic environmental assessment, taking into account societal sensitivity about environmental pollution and health risk aversion, were used as a tool for prioritization of the measures. Business as usual (BAU) is defined as present state, i.e. no additional measures to physical closing the mine as to reduce emissions from all abandoned mine facilities. This scenario has not been explored in any specific detail. Policy targets (PT) scenario is defined as collection of measures aimed at reducing introduction of mercury into Idrijca and Soča rivers; specific measures are elimination of so-called “hot spots” (sites where Hg concentrations in soil are highest), and reduction of erosion potential by land use and land cover change (primarily reforestation). This scenario has been explored in terms of modeling and institutional assessment (a questionnaire based survey). This scenario is expected to result into a 42% reduction of annual Hg emission by erosion. Total cost of the programme has been estimated at around 28 million Euros. Its effectiveness, however, is still to be determined in the future based on measurements. Deep green (DG) scenario considers measures in the coastal area, which are aimed at reducing potentials for Me-Hg formation and exposure of population to Hg. This scenario has been considered on the modelling level.

Areas of the next largest mercury release are in the vicinity of the former Idrijca mercury mine with its steep slopes and un-protective land cover (no or minimal vegetation). These areas are located in the northern part of Idrijca along the Idrijca river valley. The reduction of Hg inflow into the Gulf of Trieste from these areas, together with the “hot

spots", were the recommended for land-use change in the framework of the Policy Targets (PT) scenario.

The model shows that this scenario leads to the release of approx. 2500 kg Hg/year. Reduction of mercury input after eliminating "hot spots" and land-use change on other most polluted area (e.g. after implementing the PT scenario) would result in a reduction of mercury release of from 2500 kg/year to about 1050 kg/year. The difference between the baseline (BAU) and PT scenarios is therefore about 58 % less mercury released per year.

9. Economic impacts: Mussel farming and tourism

Eutrophication, the manifestation of nutrient-enhanced primary productivity, often indicated by the presence, not only of high chlorophyll concentrations, but also of noxious phytoplankton blooms and bottom water hypoxia/anoxia, has been reported from a variety of marine environments. The frequency of eutrophic events has increased in many coastal areas. In most EuroCat studies the scenarios deal with the impacts on concentrations of nutrients and eutrophication in general, however the AxCat regional study made it possible to illustrate links to stakeholders and economic impacts (Skourtos et al., 2003).

Eutrophication of coastal waters is linked in several ways to other environmental and resource issues. Two are very important for the Thermikos Gulf study:

1. The impact of eutrophicated waters on aquaculture, especially mussel farms – a *productivity impact*;
2. The impact of eutrophication on the ability of coastal waters to provide leisure activities – an *amenity impact*.

Both impacts are analysed at the local scale. The productivity impact signals a potentially catastrophic event for the aquacultural sector whereas the amenity impact represents an early warning for the potential of long term effects on all kinds of recreational activities in the Gulf.



Coastal stakeholders mapping of the Axios R. catchment allowed us to define in more detail the groups involved. The most important user group for this analysis is mussel farmers, a group strongly dependent on the freshwater of the Axios and in fact, the particulate matter supplied by the river. The shellfish farming activity in the Axios delta is a profitable activity comprising 85% of the total Greek shellfish output. The abundance of freshwater and particles near the Axios River mouth suggests that shellfish grow faster, resulting in larger profits for the shellfish farmers. A scarcity of freshwater (and particulates) or potential contamination, then would severely affect shellfish farming, by decreasing productivity.

During the last 20 years, a considerable growth in mussel production took place in the Axios River coastal area. To date, more than 44 pole cultures and 229 long-line cultures occupy the marine area between the Axios River mouth to the NE, whereas 37 pole and 120 pole cultures are situated to the SW of the Axios R. mouth, covering a narrow zone of ~6 km. Recently, the production has been considerably affected due to the occurrence of harmful algae blooms (HABs), which sometimes result in the accumulation of toxins in shellfish, making these dangerous or even lethal to consumers.

There is a large negative impact of eutrophic conditions on size (15%), weight (50%) and growth period of mussels. All parameters of the energy balance ('scope for growth') are negative; a fact attributed to the obvious stress conditions of the Gulf marine environment for the mussel farming. The sector exhibited high profitability in the last years (average of 75% profits before taxes), which is assumed to persist in the coming years.

According to the above, we assume that the probability of toxic blooms and consequent catastrophic events for the mussel farming remains very high in both BAUs (probability of occurrence = 0.8), high in the PT (probability of occurrence = 0.65) and reasonably under control (probability = 0.20) in the DG scenario.

A second important user group is visitors to the area, representing what we may call the local tourism sector. The coastal area east and southeast of the city of Thessaloniki has been a traditional tourist resort area for the local people.



Figure 19 Thessaloniki Beach.

An indirect glimpse at the local tourism activities can be gained from a survey in Thessaloniki aimed at analysing public preferences for cleaning up Thermaïkos coastal waters (Skourtos et al., 2004). Skourtos et al. (2004) showed that visitors 'WTP was not expressed in terms of a simple consideration of consumption of the environmental good in question, but as a complex mixture of citizen-based and consumer-based preferences. These include the environment of Thessaloniki as a whole, and may be linked to issues of self-identity and pride in the city, as well as higher moral and ethical considerations. For policy-makers, this means that an acceptable policy for cleaning up the Bay need not be based solely on considerations of water quality and extended use of the Bay for a va-

riety of activities, but on appeal to citizens concerning the quality of their local environment and their role in the future environmental quality of Thessaloniki as a whole.'

Potential economic welfare losses

Mussel farmers are a rather weak group in terms of social and economic status but an important one in terms of vulnerability. They strongly depend on future management plans since the location of their activity in the proximity of delta areas is considered to be of special ecological importance. The focus groups revealed that their perception of the impacts were framed in terms of the uncertainty in the markets for shellfish under the present conditions. The ensuing risks for the economic viability of shellfish production in the Gulf were perceived to be very high. The main reason for the expressed fear of loosing the market is negative consumer perception. They do not believe that their production is threatened in reality by quantitative and qualitative reduction due to eutrophication. Nevertheless, they foresee large economic losses in the future as a result of either real or perceived deterioration of their product, a fact that makes them reluctant to let others entering the sector.



Figure 20 Artist (M.Meybeck) impression of the potential pitfalls during the EuroCat project.

Shellfish production in the area represents 85% of the total Greek production, and increased rapidly since the 1990s to more than 30,000 tones per year, with 70-80% of the product exported to other countries. The value of the production amounts to more than 10 million € annually, and about 1,000 people are employed in the units. Mussels affected by the DSP toxin from Harmful Algal Blooms (HAB) were not released to the market at the time that bloom occurred. However, several months later, the mussels were shelf-purified, and finally the production was sold at lower prices. The economic impact

of the toxic blooms has been estimated at losses of ~3 million € per year. To estimate the expected losses for the scenarios this estimated loss from the past was multiplied by the probability of the occurrence of toxic algal blooms (see the AxCat report in Kannen et al., 2004). The estimated annual losses for the BAU, PT and DG scenarios are 2.4, 1.95 and 0.6 million € respectively. Thus even in the Deep Green scenario there is still the risk of economic losses from eutrophication.

Concerning now the losses due to the impact on the amenity functions of coastal waters, it is difficult to assess the economic cost of this massive (over the years) change. Apparently, certain land properties have been substantially devalued, while gasoline consumption (to reach clean coasts), traffic and automobile emissions increased. We could though approach the problem by taking into consideration the value of clean coastal water as captured by a contingent valuation study: there the total annual social benefits of clean coastal waters for the Thessaloniki residents is estimated at € 34.2 million. In relation to the BAU scenario, we assume that this value is totally lost. In PT we assume still a 50% loss whereas under DG conditions the marine environment and the local amenity activities will substantially (though not fully!) recover from eutrophication stress by 80%. In the DG scenario it was not possible to reach a clean environment due to boundary conditions of the system plus the fact that some sources of loads to Thermaïkos outside the catchment are still active.

10. Contaminated sediment: Rhine catchment¹

On a worldwide scale rivers are denuding continents and transporting eroded material as suspended solids to the coastal areas. Deltas, estuaries and their associated wetlands are natural sinks for this material. Man has interfered with this 'natural way of things' in three ways:

- Changes in the catchment area like agriculture, urbanisation and deforestation have changed the erosion patterns and sediment supply;
- The sediment supply itself has been decreased by damming parts of river systems; and finally;
- The composition of the sediments has been altered.

An complete overview on these changes for Europe can be found in Meybeck et al. (2004a). Notable are the increased loads of already present compounds like heavy metals but also the introduction of man-made organic substances like pesticides, polychlorinated biphenyls (PCBs) and flame retardants just to name a few.

These changes at the catchment level are a major challenge to river basin managers and to the coastal zone managers who are 'at the receiving end' of the catchment. Port authorities, for example, have to deal with the sedimentation of riverine suspended solids in their ports. Ports who require quiet conditions for the handling of cargo become efficient sediment traps. The amount of trapped sediments is enhanced when tidal action transports marine sediments/suspended solids into the harbour areas. In the case of the port of Rotterdam most of the sediments to be dredged derive from the marine environment.

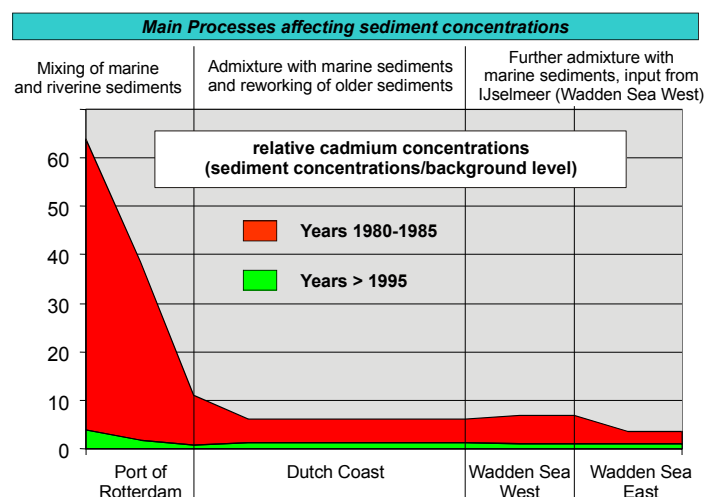


Figure 21 Development of cadmium levels in the port of Rotterdam (Rhine estuary), the Dutch coast and the Wadden Sea.

¹ The results of this highlight are drawn from a study, using the EuroCat approach, which deals with contaminated sediments in the Rhine catchment (Gandrass and Salomons, 2001).

The settled sediments, for example, spent a comparatively short time in the port areas before they are removed by dredging. Through relocation to the marine environment they are mixed with sediments already present there and continue their normal transport pattern in the coastal environment.

Since the 1970s, when the negative effects of contaminants in waterways became apparent, measures have been taken and priority chemicals for control were identified. In fact, the extent of the contamination of sediments (dredged material) made it necessary for Rotterdam to build special storage areas (Figure 22).



Figure 22 The Slufter (Rotterdam)- a confined disposal site for contaminated dredged material.

This has resulted in a significant decrease of in particular heavy metals and PCB inputs in the marine environment. In fact, the latter compounds were banned from use. The large changes in concentrations of cadmium are shown in Figure 21 relative to background values. Cadmium was selected, since it showed the highest elevated concentrations in the eighties. In the early eighties the concentration in the eastern parts of the port of Rotterdam was more than 60 times the background level, decreasing to slightly more than 10 in the Europoort in the western port area. Addition of more marine sediments along the coast and in the Wadden Sea caused a further decrease.

The decision on relocation or withdrawal (confined disposal) of sediments from the marine system should take two effects on the coastal ecosystem into account. On the one hand the withdrawal of slightly contaminated sediments will reduce inputs of contaminants (positive), on the other hand withdrawal of large amounts of sediments will upset the sediment balance in sedimentation areas (negative). In a modern impact analysis both aspects should be put in a context of questions about sustainable river management and sea level rise, with increasing coastal erosion and impact on mud flats.

In the following we will give an overview of point and diffuse sources in the Rhine catchment and identify their past, present and future inputs and how these determine sediment quality.

Inputs can be divided into the following broad categories: Indirect inputs from rural and urban areas and direct inputs, e.g. from waste water treatment plants or as discharges from industry or shipping.

Several heavy metals, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) are of concern with regard to the quality of sediments in the Rhine

catchment area and are as well criteria for the relocation of dredged material to the North Sea.

The question arises, how the contamination of dredged material will develop in future and whether it will reach levels that allow its relocation to the North Sea. For this purpose, MONERIS was adapted for heavy metals, PAHs and PCBs. Contaminant-specific information as emissions from point sources, concentrations in top soils, atmospheric deposition were gathered and used as input data.

Examples for measures that had been taken into account in the BAU and Green scenarios.

Urban areas: Decoupling of paved areas from the sewer system and enlargement of rainwater storage basins (Green). Active replacement of building materials as uncoated galvanised steel, copper and lead (Green).

Erosion: Infrastructural measures in agriculture (Green).

Waste water treatment plants (WWTPs): All WWTPs of category 3 include a denitrification step and WWTPs of category 4 a P-elimination step (BAU). Phosphorus-elimination in WWTPs of category 3 and microfiltration in largest (category 5) WWTPs (Green).

Industry: Application of 'best available techniques' (BAT)

The inputs for heavy metals, PCBs and PAHs from different sources and their contribution to contaminant loads in the Rhine system were quantified and linked to the quality of sediments/dredged material in the port of Rotterdam. Subsequently two types of scenarios were modelled, taking the present state as a starting point, for the time period until 2015.

The 'business as usual' (BAU) scenarios take measures into account, which are already agreed on or are 'in the pipeline', i.e. the implementation can most probably be expected. The 'Green' scenarios include additional reduction measures that might be realised but largely depend on upcoming policies. Contribution of different relevant sources/pathways are illustrated for zinc and benzo(a)pyrene, a polycyclic aromatic hydrocarbon, in Figure 23.

Taking the present state as a starting point, the changes in modelled future inputs in the Rhine basin were extrapolated on the development of the quality of sediments in the eastern parts of the Port of Rotterdam and were compared to Dutch quality criteria (2002) for relocation of dredged material to the North Sea.

Measures, accounted for in the BAU scenarios, are not expected to result in a substantial decrease in contamination of sediments/ dredged material for most of the investigated substances. Additional measures (Green scenarios) could achieve more satisfying results. However, even in the Green scenarios, defined target values will still be exceeded for the investigated compounds until 2015, with the exception of lead.

Pathways incorporating the highest reduction potentials for copper, zinc and cadmium are inputs from urban areas, from wastewater treatment plants and to a lesser extent erosion from agricultural areas. Additional related measures, bringing the highest net reductions, are substitution of building materials as uncoated galvanised steel and copper, decoupling of paved urban areas from sewer systems, enlargement of rainwater storage basins and erosion reduction measures in agricultural areas.

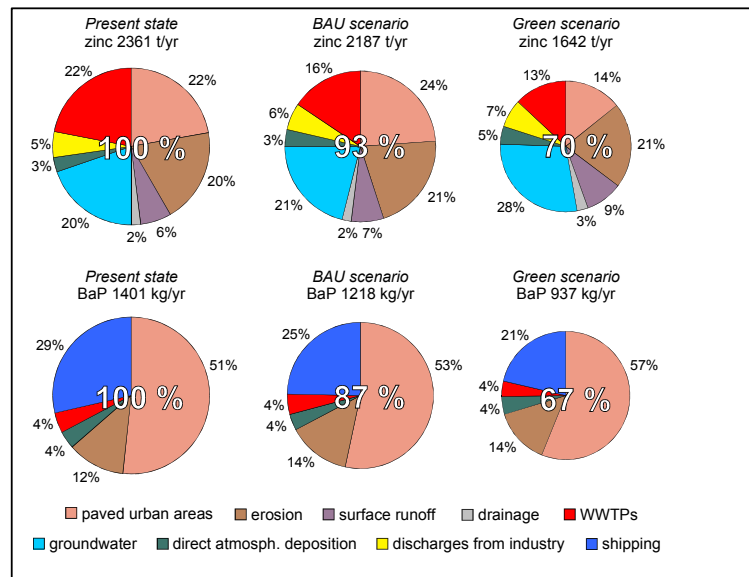


Figure 23 Results of the scenario analysis for zinc and benzo(a)pyrene inputs in the Rhine basin upstream Bimmen/Lobith.

PAHs are mainly released by combustion of fossil fuels and related processes resulting in elevated atmospheric deposition rates in urban areas. This pathway and related additional measures, especially towards emissions from residential combustion, incorporates the highest reduction potential.

PCBs, used e.g. as dielectrics in capacitors and transformers or as hydraulic oil in mining, have been banned in many countries and are restricted in marketing and use by the European Council Directive 76/769/EEC. New PCB inputs are mainly driven by atmospheric deposition, re-emissions from soils becoming more important. Major pathways are paved urban areas and direct atmospheric deposition on surface waters. Additional reduction measures are decoupling of paved urban areas from sewer systems and enlargement of rainwater storage basins.

An issue of special importance for PCBs is the 'historic' contamination of sediments in the Rhine basin. As new inputs of PCBs will continue to decrease, the relative contribution of 'historically' contaminated sediments to PCB loads in the Rhine basin will gain in importance. This process, is governed by re-erosion during high water discharges, by relocation of dredged material stemming from weirs and locks in the upper Rhine or tributaries of the Rhine and related retention and loss processes.

11. Drivers, pressures and impacts at the European scale

All the countries in the European region (i.e. EU countries and the 12 countries of Eastern Europe, the Caucasus & Central Asia) are under environmental pressure from generic driving forces within the globalisation process. But the impacts of these environmental changes are not uniformly intense and policy responses are also non-uniform across Europe. (Figure 24) While all countries face the 21st century challenge of sustainable economic development only limited progress has so far been made in terms of more efficient resource utilisation. While gross domestic products (GDPs) are no longer tied inexorably to increasing resource use (at least in Western Europe) the absolute level of material use is still probably unsustainable given foreseeable technological advances. The countries of Central and Eastern Europe face the additional dilemma of achieving Western European levels of socio-economic welfare via a growth process that needs to be constrained by sustainability principles and objectives. While per capita GDP grew on average from \$9000 in 1972 to \$13,500 in 1999, wide variations exist across Europe. In Western Europe the average was \$25,441 in 1999 but only \$3,139 in Central Europe and \$771 in Eastern Europe.

Europe's population has grown by 100 million since 1972 and totalled some 818 million in 2000 (13.5% of the global total). The most significant demographic trends in Europe are the overall ageing of the population, the increasing number of households and the increasing mobility of people throughout Europe.

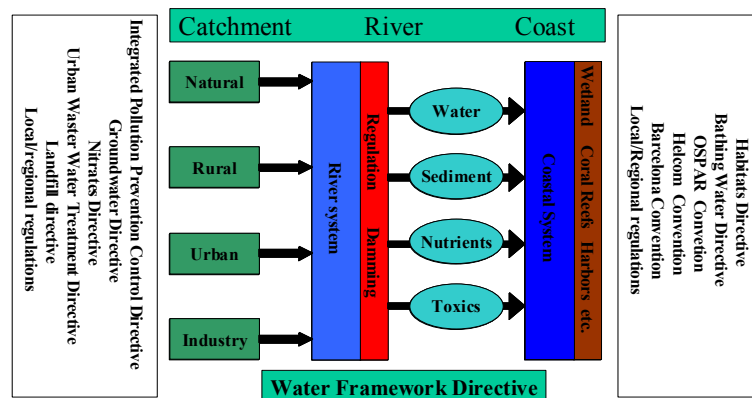


Figure 24 The land-based point and diffuse sources (natural, rural, urban, industry) which contribute to the fluvial fluxes of water, sediment, nutrients and toxics to the coastal region and their (partial) embedment in European Regulation (examples) (based on Ledoux and Turner, 2003a).

At the generic level, all European countries are engaged in growing and extensive trading activities. This is putting severe pressure on 'local' coastal areas, as well as possibly shifting other environmental cost burdens to other regions around the globe. Imports currently constitute around 40% of the total material requirement of the EU and they grew rapidly in the 1990s. Maritime transport increased by 35% in the EU between 1975-85 but has since levelled off. Nevertheless, it accounts for 10-15% of total SO₂ emissions and in the Mediterranean oil spill and related risks are high because of the volume of

traffic. Some 30% of all merchant shipping and 20% of global oil shipping crosses that sea every year. Ports and associated industrial development are responsible for land conversion/reclamation, loss of intertidal and other habitats, dredging and contaminated sediment disposal, increased flood protection measures and also facilitate the spread of invasive exotic species thereby causing 'local' biodiversity loss.

The increasing physical growth of the European economies manifests itself, among other ways, in massive new construction of buildings and infrastructure. The spread of the built environment is having profound effects on catchment-wide processes, leading to increased flood risk, changes in sediment fluxes (and contamination risks) as well as habitat and biodiversity loss in the catchment-coast continuum. Direct physical alteration and destruction of habitats because of 'development pressure' is probably the most important single threat to the coastal environment. But human-induced changes in the natural flow of sediments are also a contributory threat to coastal habitats. Deltaic areas such as the Po, Rhone and Ebro have suffered from sediment starvation as hydrological changes in catchments (dams etc) have cut sediment supplies. The built environment expansion has multiple causes, but two factors are especially relevant for coastal areas, transport and tourism.

Fluxes and long-term decrease of river water discharges in Mediterranean rivers.

The consumptive use of water in the Mediterranean region, particularly for irrigation results in a general decrease of water discharges to the coastal zone. The Med-Hycos database has more than 30 river stations for which more than 50 years of discharge data are available. The only slight positive trend is noted for the Têt river (E; Pyrenées mountains) and is attributed to a increase of rainfall during that period. The Pô and the Rhône rivers do not present a significant trend. The Ebro (Spain) discharge has been decreased by 47% and similar rates of decrease are noted for the Adige, Arno, Pescara, Tiber, Ofanto in Italy. Such rates are very likely to be found as well in Spain for other Mediterranean rivers heavily impacted by reservoir cascades.



In other Mediterranean regions, the decrease is similar as for the Medjerdale, the most important Tunisian river, for Albanian, Greek and Croatian rivers.

According to Ludwid last review the fresh water discharge to the Mediterranean by rivers is now only 330 km³/y compared to about 600 km³/y at the beginning of the XXth century.

As a consequence the inputs of nutrients, organic carbon and contaminants to the Mediterranean Sea has not increased as fast as for the other European rivers under heavy Human pressures. For the Nile the increases of nutrients concentrations downstream of Cairo from 1960 to 2000 is now compensating the decrease of water fluxes: the Nile nutrients fluxes to the Mediterranean are now of the same order as they were in the 1960's.

From the EuroCat report Meybeck et al. (2004b)

Road transport is the dominant mode in Western Europe, not least because, despite tax escalators, fuel for road transport remains perennially cheap and fuel-efficiency provisions for vehicles remain voluntary. Rail networks are somewhat better developed in Central and Eastern Europe, but the 'lure' of the car/lorry poses a strong threat to any future transport strategy. Transport infrastructure and trade are strongly linked and so coastal habitats and ecosystems face fragmentation along with other with other areas close to main arterial transport routes. The official European investment agencies have biased their landing heavily in favour of road projects e.g. between 1992-2000 the European Investment Bank gave 50% of its loans to road projects and only 14% to rail.

Europe's coasts host around 66% of the total tourist trade, and in the Mediterranean, for example, arrivals are expected to grow from 135 million per annum in 1990 to as many as 353 million by 2025. Tourism's main environmental impacts are also generated via transport requirements, together with use of water and land, energy demands and waste generation. In some popular Southern European localities irreversible environmental degradation has probably already been inflicted. Tourism-related demand for passenger transport (pre 'nine eleven') has grown remorselessly, arrivals in South Western Europe grew by 91% 1985-2000. The environmental impacts are highly concentrated and seasonal within or close to resort areas. But lateral expansion along coastlines is also a common phenomenon and the construction of second homes (the Mediterranean and Baltic areas are prime examples) is a particular concern.



Figure 25 The port of Rotterdam.

Europe's semi-enclosed and enclosed seas (with their limited water exchange) are particularly sensitive to pollution threats. Marine and coastal eutrophication from elevated nitrogen levels (riverine transport and atmospheric deposition) quickly emerged as a worrying trend, the impacts of which were exacerbated by the loss of natural interceptors such as coastal wetlands. Severe eutrophication has occurred in the Black Sea and in more limited areas in the Baltic and Mediterranean. A majority of European countries have made significant progress in combating point-source pollution of watercourses, estuaries and coasts (e.g. sewage treatment plants and industrial facilities). So discharges of heavy metal and organic substances into the North East Atlantic fell during the 1990s. Nitrate concentrations fell by 25% in the Baltic and North East Atlantic over the period

1985-98 and phosphate concentrations also fell in North Sea areas. Waste water treatment levels and discharges are still problematic in the Mediterranean, Adriatic and Black Sea areas. However, the issue of diffuse pollution at the catchment scale and beyond remains generally problematic.

Agricultural activities and run-off are one of the contributors to this problem. Overall consumption of fertilizers in Europe has stabilised in recent years following a fall in the early 1990s in Central and Eastern Europe. Current levels of fertilizer and pesticide use are probably not environmentally sustainable and measures such as integrated crop management need to be adopted more widely (3% of the utilised agricultural area of Europe is under such integrated management by 2003). Irrigated cropland retains a significant share of the agricultural areas in Western, Central and Eastern Europe, ranging from 11% to 18% respectively. Irrigated land continues to expand in some Western European and Mediterranean areas. This type of production has serious water resource implications and also poses a major threat to wetlands. The Aral Sea catchment serves as an extreme warning as to what processes could unfold. Although the threats are varied some 31% of Europe's population now lives in countries that use more than 20% of their annual water resource.



Figure 26 Farming in the coastal zone.

IdriCat outcomes.

1. Significant improvements of the existing Hg transport and transformation river-model MeRiMod to local conditions in Idrijca&Soca river catchments;
2. Development and application of the erosion model for the catchment, improved emission inventory of the 500 years Hg mining and development of an improved monitoring strategy in areas impacted by mercury mining recognition and last but not least an appreciation of differences between natural and social views in the segment of environmental modelling by all involved researchers;
3. The Eurocat/Idricat project has clearly demonstrated how society can develop more consolidated long-term economic and environmental decision making taking into account results of mass balance modelling and health risk due to assumed exposure to a certain pollution. There was a lack of so wide recognition in the past among natural scientists in Slovenia: most often, environmental mass balance modelling has been understood as an important tool per-se and was not integrated into servicing social needs;
4. Recognition of the need for an open and creative collaboration among countries in the catchment. In the context of the sequence "source of pollution - consequences - response policy" it is difficult to follow the DP-S-I-R concept if the costs and benefits are unfairly distributed among countries, and if not all parties are involved in the assessments.

M. Horvat-IdriCat

Most of the capture fisheries of Europe have now been over-exploited and other substitute populations also denuded. But while fisheries production has declined, marine aquaculture in Western Europe has increased significantly. This development threatens the nutrient status of receiving waters and remaining natural fish stocks if controls are not imposed.

Table 5 Drivers, State Changes and Impact assessment for European regional seas.

	Arctic	Baltic Sea	Black Sea	Caspian Sea	Mediterranean	North Sea	Atlantic Coast
Main driving pressures							
Climate Change (CC)	CC+	CC	CC+	CC+	CC (locally+)	CC (locally+)	CC
Built Env. Expansion	-	BE+	BE	-	BE+	BE	BE
Trade, ports & related industry (P)		P+	P+	P+	P+	P+	P
Tourism (T)	-	T+	T (locally+)	-	T+	T	T
Fishing & aquaculture (F)	F+	F+	F+	F+	F+	F+	F+
Agriculture (A)		A+	A+	A+	A	A	A
Environmental state change / Impacts							
Contamination (C)	C	C (locally+)	C+	C+	C (locally+)	C+	C (locally+)
Eutrophication (E)		E+	E+	E+	E (locally+)	E	E (locally+)
Biodiversity loss (incl. invasive exotic impact) (B)	B	B (locally+)	B+	B+	B (locally+)	B (locally+)	B
Sea level rise & coastal erosion (SE)	SE	SE+	SE	SE+	SE+	SE (locally+)	SE

Notes: + = Very significant; - = minor to insignificant; Contamination = heavy metal accumulation, pesticide etc; residue accumulation, oil and gas spills; ICZM = demonstration projects, training and evaluation; Source: European Environmental Agency.

Climate change is expected to cause significant impacts across Europe, but the south and the European Arctic are possibly the most vulnerable areas (with the caveat that some 'local' areas are especially at risk for sea level rise e.g. South East England. All areas face hydrological and water resource risk increases which may then affect ecosystems and biodiversity, as well as human health. If the modelling predictions about changes in marine water circulation patterns turn out to be correct then there are significant negative implications for regional seas in terms of eutrophication and contamination.

The Caspian Sea provides an alarming example of the combined negative effect of temperature and precipitation change. It has recently risen by 2.5 m causing severe flooding and damage costs. It is predicted that by 2020-40 an additional 1.2 - 1.5 m increase is possible.

Europe's forests can play an important role in any climate change mitigation policy. The total area of forest in Europe is increasing and there is a future opportunity to diversify its service functions in order to provide watershed protection from soil erosion and floods and excess sedimentation, as well as realise carbon sequestration, recreation and nature conservation benefits. This reinforces the point that coastal zone management requires an appreciation of measures deployed within the relevant catchments if it is to be effective.

The concept of a more integrated coastal management approach has been advocated for more than a decade but so far full adoption has not been practised anywhere. In Western Europe, awareness has been raised but sectoral policies have not been radically modified, let alone integrated. More generally, only 15% of Western Europe is under national designation for nature conservation and 9% or less elsewhere in Europe. Table 12.1 presents an overview of a DP-S-I-R scoping exercise for European coastal areas. This table is the result of a scoping exercise using expert opinion during an Eloise conference in 2003. The results clearly show that the enclosed regional seas with their long residence time of the water are much more impacted compared with the relative open North Sea or the Atlantic Coast. It remains the case that 85% of Europe's coast face moderate to high risk from economic development – related pressures and some 25% of the coastline is subject to erosion. Hard engineering sea defences have been the traditional response to erosion and flooding risks. These defences, however, also reduce sediment input to the coastal system hence intensify erosion and accelerate the need for additional defences. Armouring the coastline this way is essentially unsustainable on economic cost grounds alone.

12. Drivers, pressures and impacts at the global scale (LOICZBasins assessment)

The EuroCat project is part of the Eloise contribution to the international IGBP-LOICZ program. Within LOICZ a program was started in 2001 called LOICZBasins which deals the same issues which addresses as EuroCat the impact of catchments on the coast.

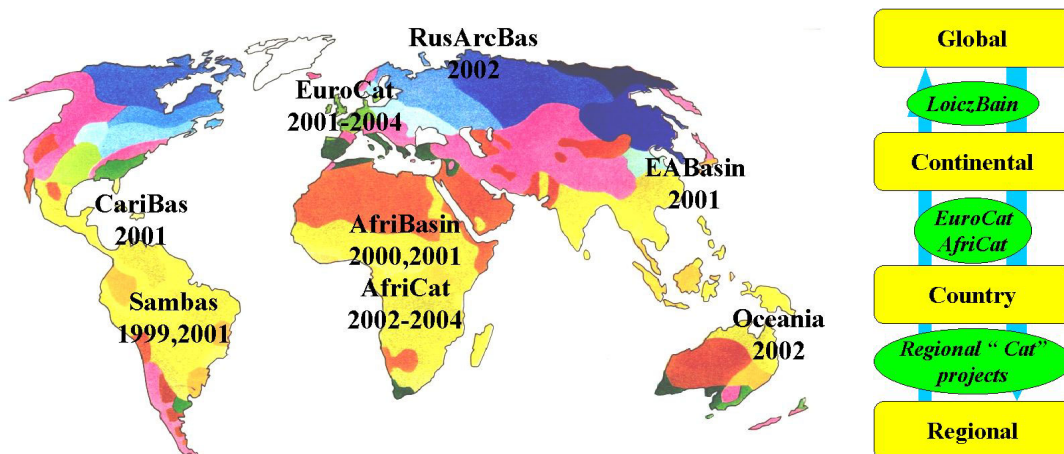


Figure 27 The catchments and coastal regions, which are part of the LOICZBasins study and the hierarchy of the individual studies.

Within LOICZBasins a standardised framework of analysis was developed to assess the impact of land-based sources (and in particular catchments) on coastal systems (Kremer et al., 2001). To date close to 100 catchment-coastal sea systems have been analysed through workshops and desktop studies. In addition the individual assessments were scaled up to coherent continental regions. This expert assessment differs from the Scoping exercise in EuroCat because of its standardised approach.

For this assessment (as in EuroCat) the Coastal Sea and its associated catchment(s) are treated as one system.

The LOICZBasins assessment follows a hierarchy of scales finally generating a composite regional picture – the scales range from:

- local catchments, to
- national e.g., Brazil or
- sub-regional or provincial levels, to
- full regional i.e. sub-continental or even continental.

The steps taken are:

- to set up a list of coastal change issues and related drivers in the catchment.
- to characterise and rank the various issues of change based on either qualitative information (i.e., expert judgment) or quantitative data; this step includes identification of critical load and threshold information for system functioning where available.

Since each continent or sub-continent has its own team of experts, it is only valid to compare the internal impact assessments. E.g. an impact assessment marked as major in continent A is valid for that continent in its relation to the other impacts. Nevertheless, in each case the reasoning behind the assessment is backed up with literature data whenever available. The reader is referred to the original reports, which are listed in Appendix I.

Table 6 Summary tables for the LOICZ Basin assessment.

Ranking	Antropogenic drivers	Major state changes and coastal impacts	Present pressure status	Trend expectation
South America				
1	Urbanisation	Eutrophication	Major	↑
2	Damming/diversion	Erosion/sedimentation	Major	↑
3	Industrialisation	Pollution	Medium	↑
4	Agriculture	Eutrophication/pollution	Medium	↑
5	Deforestation	Erosion/sedimentation	Medium	↑
6	Aquaculture	Eutrophication	Low	↑
7	Navigation	Erosion/sedimentation	Low	→
8	Fisheries	Loss of biodiversity	Low	→
9	Tourism	Erosion/eutrophication	Low	↑
10	Mining	Erosion/pollution	Low	↓
Africa				
1	Damming/diversion	Erosion/sedimentation	Major	↑
		Salinisation	Local	
		Nutrient depletion	Local	
2	Various drivers	Biodiversity loss	Major	↑
3	Deforestation	Erosion/sedimentation	Medium	↑
4	Agriculture	Eutrophication/pollution	Medium	↑
5	Urbanisation	Eutrophication/pollution	Medium	↑
6	Industrialisation	Pollution	Medium	↑
East Asia				
1	Urbanisation	Eutrophication/ water extraction	Major	↑
2	Agriculture	Eutrophication/pollution/ reclamation/disease	Major	↑
3	Damming/diversion	Erosion/sedimentation/ nutrient depletion	Major	↑
4	Industrialisation	Pollution	Minor	↑
5	Deforestation	Erosion/sedimentation	Major	↑
6	Land reclamation	Erosion/sedimentation	Minor	↑
7	Mining (incl. offshore)	Habitat loss/biodiversity	Medium	↑
Russian Arctic				
1	Industrialisation	Pollution (incl. Thermal)	Major	↑
2	Navigation	Erosion/sedimentation	Medium	↑
3	Damming	Erosion	Medium	↓
4	Agriculture	Nutrient, water, sediment	Minor	→
5	Urbanisation	Nutrient, water extraction	Minor	→

Large catchments seem to be obvious examples to be addressed within a global LOICZ synthesising effort (e.g. Amazon, Nile, Yangtze, Orinoco). However, from the perspective of coastal change, the major influence from land-based flows is more often gener-

ated in small to medium catchments with high levels of socio-economic activity. Here, changes in land cover and sectoral use need much shorter time-frames to translate into coastal change and usually exhibit more visible impacts than in large catchments where the “buffer capacity” against land-based change is higher simply because of catchment size. Thus, small and medium catchments are a priority for the global LOICZBasins assessment. They dominate the global coastal zone (in Africa, for example, they characterise extensive parts of monsoon-driven runoff to the Indian Ocean).

The results from the LOICZBasins and EuroCat assessments show the ranking of main drivers and pressures is strongly influence by local conditions. Damming and its influence on the coast top the list in Africa and is also high on the list in South America and East Asia. The driver for eutrophication of coastal waters in Europe is agriculture, however urbanization is more important in South America and East Asia. As expected it has a low ranking for Africa. Deforestation, a major issue in land-use change, is a low-ranking driver for coastal change. Also, unlike Europe, the other continents don’t consider sea level rise as a major driver for change. Industrialisation only ranks very high in the Russian Arctic (in this case in particular the (past) release of radionuclides).

This high variability in regional drivers-pressures and impacts clearly shows the need for flexible coastal zone management approaches therefore its underlying tools have to be flexible and adaptive to local conditions.

13. Relevance for European directives and strategies

Many parts and outcomes of the research project of EuroCat are of direct relevance to European directives and strategies such as the Water Framework Directive (WFD) and the EU Marine Strategy. In this chapter we will identify pertinent results.

Implementation Strategy of the Water Framework Directive.

- 1. Sharing Information**
 - 1.1 Tools for Information Management
 - 1.2 Raising Awareness
- 2. Develop Guidance**
 - 2.1 Analysis of pressures and impacts
 - 2.2 Heavily modified waterbodies
 - 2.3 Reference conditions inland surface waters
 - 2.4 Typology, classification of transitional, coastal waters
 - 2.5 Intercalibration
 - 2.6 Economic analysis
 - 2.7 Monitoring
 - 2.8 Tools on assessment, classification of groundwater
 - 2.9 Best practices in river basin planning
- 3. Information Management**
 - 3.1 Geographical information systems
- 4. Application, testing and validation**
 - 4.1 Integrated testing in pilot river basins

EuroCat has a strong sense of information sharing (activity 1 of the WFD.) The website www.iiia-cnr.unical.it/EuroCat/project.htm gives general information on the project, the regional activities and listings, while making available all results to the general public. Further a key role was played by the regional Policy Advisory Boards (PAB). These PAB's interacted with the regional teams (see website for details on composition and meetings), contributing to the set-up of the regional projects, the development of scenarios and the specification of policy implications. In this way an attempt was made to bridge the "science-policy-gap". Chapter 6 highlights the use of multi-criteria analysis in presenting and evaluating results of interaction with stakeholders. To date the information sharing with fellow scientists has been extensive: 21 peer reviewed papers have been published and another 22 are already submitted or forthcoming. During the lifetime of the project (2001-2004) 118 papers were presented at national and international scientific meetings. For internal communication in the project we produced 44 documents.

The Scoping exercises using the DP-S-I-R framework to identify pressures and impacts at the regional Catchment-coast level are directly related to section 2.1 of the WFD Implementation Strategy. Eutrophication was considered to be important for the Vistula, Elbe, Rhine, Humber, Po, Axios and Provadijska Studies. Heavy metals (mercury) were of prime concern in the Idrijca case study and also identified for the Humber as a major issue.

Existing mathematical models for the catchments and the coast were identified and linked. In this way EuroCat provided a first linked-model exercise relevant for the catchment-coast system in the WFD. An important point here is, that we did not consider political and regulatory boundaries for the coast but rather those relevant from a biophysical viewpoint. Hence the modelling considers, for instance, the North Sea, the Baltic and the Northern Adriatic. These approaches have their relevance for the HelCom,

OsPar and Mediterranean conventions as well as for the EU Marine Strategy. The numerous treaties and policies in the various regional studies which are relevant for the catchment-coast continuum have been compiled (Lukewille, 2003), analysed (Ledoux and Turner, 2003a) and put in an European perspective (Hisschemöller and Van Tilburg, 2004). Chapters 4 and 5 highlight catchment and marine modelling, Kannen et al. (2004) summarizes the results within EuroCat on marine modelling and the attachment gives a complete account of the models used and their link with the catchment models and the scenarios. Catchment modelling discussed in detail in Behrendt (2004).

PoCat outcomes.

1. The scenario analysis performed by the PoCat consortium was finalized to verify the achievement of the WFD 2000/60/EEC targets.
2. The effectiveness of different policy options adopted for different Policy target scenarios show that the implementation of the European water policy is an important requisite to achieve the 'good' qualitative state for the Po River, however the eutrophication of the Adriatic Sea requires additional legislative restrictions.
3. The evaluation of 'Basin Plan' (as targeted by the WFD) is the crucial step for the eutrophication of the Adriatic Sea. The scientific outcome of this project has a strategic relevance because it evaluates the effects of all legislative restrictions and ongoing plans implemented at Italian level. The PoCat results should be regarded, as starting point in the implementation of further legislative restrictions.
4. The Po Basin Area being 'strategic' for the Italian economy, the sustainable development and the adoption of additional precautionary legislation requires the full participation of all interested parties at different institutional levels including stakeholders groups.

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EuroCat's approach is highly relevant for guidance on River Basin Planning, since it has developed a methodology for testing management options based on scenarios. An illustration on how to evaluate management options is presented in Section 6. A complete review and digest of the results of the regional studies can be found in Turner (2004). A full-scale quantitative economic analysis has been carried out for the Elbe and Rhine catchments and the North Sea (details on the CENER model in Lise, 2004).

The typology (spatial structure) of European Catchment-Coast continua and the EuroCat regional studies are discussed in "Space Analysis of Catchment-Coast Relationships" (Meybeck et al., 2004b) which is part of the European upscaling effort of EuroCat. The critical review and analysis of past river basin management policies (Hisschemöller and Van Tilburg, 2004, in Meybeck et al., 2004b) assists in identifying best practices.

Monitoring data have been extensively used in the modelling approaches in EuroCat recommendations on improving monitoring, taking into account the catchment-coast continuum, are discussed in Meybeck et al. (2004b).

Appendix I. Key documents

Integrated documents

- Behrendt H (2004). *Past, Present and future changes in catchment fluxes*, 230 pp.
- Colijn F., Kannen, A. & Windhorst, W. (2003). *List of indicators and critical loads*, 38 pp.
- Davies H. (2002). *Quality assurance guidance manual*, 55 pp.
- EuroCat (2004). *Scoping studies*, 262 pp.
- Kannen A., Windhorst, W. & Colijn, F. (2004). *Scenario based impact assessments for coastal waters*, 354 pp.
- Ledoux L., & Turner, K. (2003a). *Institutions, stakeholders and potential/actual conflicts of interest and values within a given catchment*, 71 pp.
- Ledoux, L., & Turner, K. (2003b). *Scenario Analysis*, 121 pp.
- Lukewille, A. (2003). *Inventory of national and international treaties and regulations relevant for the EuroCat catchment case studies*, 155 pp.
- Salomons, W. (2004). *European Catchments: Catchment Changes and their Impact on the Coast*. 44pp.
- Turner, K. (2002). *Guidelines for Scenarios, Modelling and Institutional/Policy analysis: The "Rhodos" report*, 51pp.
- Turner, K. (2004). *Assessment of (redefined) scenarios, policy options and their effectiveness*, 382 pp. Part 1: Reb Cat and HumCat. Part 2: PoCat. Part 3: AxCat, VisCat, IdriCat and ProvaCat.

Reports on integration at the European level

- Meybeck, M., Duerr, H., Vogler, J., Lacharte, L. & Gueguen, Y. (2004a). *Space analysis of catchment/coast relationships*, 166 pp.
- Meybeck, M., Vogler, J., Moatar, F., Duerr, H., Laroche, L. & Lachartre, L. (2004b). *Analysis of temporal variability in river systems*, 90 pp.
- Meybeck, M., Vogler, J., Turner, K., Hisschemöller, M. & Tilburg, M. van (2004c). *River-Coast Integration in European Regional Seas*. Part I: Improving basin-coast integration (Meybeck & Vogler) . Part II: Scenario Analysis (Turner). Part III: Institutional Analysis (Hisschemöller & Van Tilburg). 129 pp.

"Stand alone" Reports from the Regional Catchment-Coast studies

- Artioli, Y., Bendoricchio, G., Palmeri, L., Trombino, G., Pirrone, N., Cinnirella, G., Algieri, A. (2004). *Modelling the North-western Adriatic Coastal Zone*, 69 pp.
- Behrendt, H., & Hofmann, J. (2001). *General description of the Rhine Catchment*, 26 pp.
- Behrendt, H., & Hofmann, J. (2002). *The Elbe catchment and related coastal area: German Bight and Wadden Sea*. Part A. Catchment profile, 24 pp.
- Cave, R., Brouwer, R., Coombes, E., Hadley, D., Turner, K. & Lorenzoni, I. (2003b). *Futures Scenarios and Cost Effectiveness Analysis of Alternative Policy Options to Improve Water Quality in the Humber Catchment in the United Kingdom*. 130 pp.
- Cave, R., Ledoux, L., Jickels, T. & Andrews, J. (2002). *The Humber Catchment and its Coastal Area*. 26 pp.

- Cave, R., Ledoux, L., Jickels, T., Andrews, J., Turner, K., Brouwer, R., Coombes, E., Lorenzoni, I., & Hadley, D. (2003a). *HumCat: Evaluation of the scenarios*, 23 pp.
- Colijn F., Windhorst, W. & Kannen, A. (2002). *The Elbe catchment and related coastal area: German Bight and Wadden Sea. Part B. Physiographic profile with focus on eutrophication*, 32 pp.
- Doncheva, V., Moncheva, S., Racheva, E. & Ikononov, L. (2003). *Nutrient Fluxes in Varna Lakes - Varna Bay System*, 11 pp.
- Hisschemöller, M. & Tilburg, M. van (2004). *Institutional analysis EuroCat*, 50 pp.
- Horvat, M (2003). *IdriCat: Scenarios, institutions, stakeholders, modelling and assessment*, 103 pp.
- Horvat, M., Jereb, V., Fajon, V., Logar, M., Kontic, B., Faganeli, J., Rajar, R., Sirca, A., Zagar, D. & Kotnik, J. (2003). *Idrijca Catchment*, 6 pp.
- Kannen, A., Windhorst, W. & Colijn, F. (2002). *The Elbe catchment and related coastal area: German Bight and Wadden Sea. Part C. Socio-Economic and institutional profile*, 45 pp.
- Karageorgis, A. (2001). *General description of the Axios River catchment and the Gulf of Thermaikos*, 20 pp.
- Kot-Wasik, A., Pacyna, J., Buszewski, B. & Naniesik, J. (2002). *The conditions of the Polish Baltic sea coastal zone*, 44 pp.
- Kowalewski, M., Jedrasik, J., Oldakowski, B. & Nowacki, J. (2003). *The impact of the Vistula river on the coastal waters of the Gulf of Gdansk*, 70 pp.
- Kowalkowski, T., & Buszowski, B. (2003). *Modelling of past, present and future state of nutrient emissions into the Vistula river system*, 47 pp.
- Kubata, S., Laane, R., Geurtz, M. & Lise, W. (2003). *General description of the Rhine coastal area*, 39 pp.
- Lenhart H.-J., H.J (2004). *ERSEM Application of Moneris river loads. Reduction Scenarios*. 93 pp.
- Lise, W. (2003). *Cost-Effective Nutrient Emission Reduction (CENER) of the load to the North Sea from the Rhine and Elbe Basin*, 60 pp.
- Lise, W., Janssen, R., Herwijnen, M. van & Brander, L. (2004). *Reducing nutrients in the Rhine/Elbe–North Sea continuum: a Multi-Criteria Analysis*, 30 pp.
- Moncheva, S. (2003). *Provadijska Catchment*, 36 pp.
- Nikolaidis, N., Karageorgis, A., Kapsimalis, V., Drakopoulou, P., Skoulikidis, N. & Behrendt, H. (2004b). *Modelling of Axios River Basin*, 41pp.
- Nikolaidis, N., Karageorgis, A., Kapsimalis, V., Marconis, G., Drakopoulou, P., Kontoyiannis, H., Krassakopoulou, E., Pavlidou, A., & Pagou, K. (2004a). *Modeling of Thermaikos Gulf*, 50 pp.
- Nunneri, C., Moncheva, S. & Doncheva, V. (2004). *Present Perceptions, Future Trends: a Stakeholder Insight about the Development and the Management of the Varna and Shoumen Region (Bulgaria)*, 25 pp.
- Palmeri, L., Bendoricchio, G., Artioli, Y., Trombino, G., Pirrone, N., Cinnirella, S., & Algieri, A. (2004). *Modelling of Po River Basin*, 60 pp.
- Panasiuk, D., Bartczak, A., Giergiczny, M., Kaniewska, M., Panasiuk, D., Sleszynski, J. & Zylicz, T. (2003a). *Redefinition of scenarios and analysis of outcomes*, 30 pp.
- Panasiuk, D., Bartczak, A., Kaniewska, M., Markowska, A. & Zylicz, T. (2003b). *VisCat's institutional assessment of scenarios, policy options and their effectiveness*, 42 pp.

- Pirrone, N., Trombino, G., Cinnirella, S., Algieri, A., Bendoriccho, G., Palmeri, L., & Artioli, Y. (2004). *PoCat: Redefinition of scenarios and institutional assessment of scenarios, policy options and their effectiveness, and analysis of outcome*.
- Pirrone, N., Trombino, G., Presenti, E. & Palopoli, P. (2002). *General description of the Po river catchment and the Northern Adriatic Basin*, 43 pp.
- Skourtos, M., Kontogianni, A., Zanou, B., Karageorgis, A. & Nikolaidis, N. (2004). *PoCat: Redefinition of scenarios and institutional assessment of scenarios, policy options and their effectiveness, and analysis of outcome*, 34 pp.
- Skourtos, M., Kontogianni, A., Zanou, B., Nikolaidis, N., Karageorgis, A. (2003). *Evaluation of scenarios in AxCat*, 32 pp.
- Totev, S., & Chkorev, N. (2003). *Economic Profile and Sustainable Development of Provadijska Catchments Area*, 38 pp.

EuroCat peer reviewed publications and conference contributions

A total (as of 1-2-2004). of 15 peer reviewed articles have been published, 18 are submitted or in press, this includes one special journal issue. 120 oral presentations have been given at conferences. The complete list and most of the articles and abstracts are available in the directory "Publications" of the enclosed CD.

EuroCat related Studies

- Arthurton, R.S., Kremer, H.H., Odada, E., Salomons, W. & Marshall Crossland, J.I. (2002). *African Basins: LOICZ Global Change Assessment and Synthesis of River Catchment-Coastal Sea Interactions and Human Dimensions*. LOICZ Reports & Studies No.25, ii + 344 pages, LOICZ IPO, Texel, The Netherlands.
- Gandrass J., & Salomons, W. (2001). *Dredged Material in the Port of Rotterdam - Interface between Rhine Catchment Area and North Sea –Executive Summary*, 20 pp.
- Hong, G.H., Kremer, H.H., Pacyna, J., Chen, C.-T.A., Behrendt, H., Salomons, W. & Marshall Crossland, J.I. (2002). *East Asia Basins: LOICZ Global Assessment and Synthesis of River Catchment-Coastal Sea Interaction and Human Dimensions*. LOICZ Reports & Studies No. 26, ii + 262 pages, LOICZ IPO, Texel, The Netherlands.
- Kjerfve, B., Wiebe, W.J., Kremer, H.H., Salomons, W., Morcom, N. Harvey, N. & Marshall Crossland, J. I. (2002). *Caribbean Basins: LOICZ Global Change Assessment and Synthesis of River Catchment/Island-Coastal Sea Interactions and Human Dimensions; with a desktop study of Oceania Basins*. LOICZ Reports & Studies No. 27, ii + 174 pages, LOICZ IPO, Texel, The Netherlands.
- Kremer, H.H., Salomons, W. & Crossland, C.J. (2001). *Human dimensions of land-based fluxes to the coastal zone: LOICZ-Basins approach*, 13 pp.
- Lacerda, L.D., Kremer, H.H., Kjerfve, B., Salomons, W., Marshall Crossland, J.I. & Crossland, C.J. (2002). *South American Basins: LOICZ Global Change Assessment and Synthesis of River Catchment – Coastal Sea Interaction and Human Dimensions*. LOICZ Reports & Studies No. 21, ii + 212 pages, LOICZ IPO, Texel, The Netherlands.

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